

CHAPTER TWO: HYDROLOGY

2.1 GEOGRAPHY

The Pinal Active Management Area (PAMA) covers approximately 4,000 square miles in central Arizona. The topography consists of gently sloping alluvial basins separated by north to northwest trending fault-block mountains. Land surface elevations range from 1,000 to 4,000 feet above sea level. The PAMA consists of five sub-basins with unique groundwater underflow, storage, and surface water characteristics. These sub-basins are: Maricopa-Stanfield, Eloy, Vekol Valley, Santa Rosa Valley, and Aguirre Valley. The boundaries of the sub-basins generally follow the topographic divides separating areas from where surface water runoff emanates. The boundaries that separate the Eloy and Maricopa-Stanfield sub-basins also signify the presence of groundwater divides that define the extent of groundwater underflow. Migration of groundwater underflow between these sub-basins is limited.

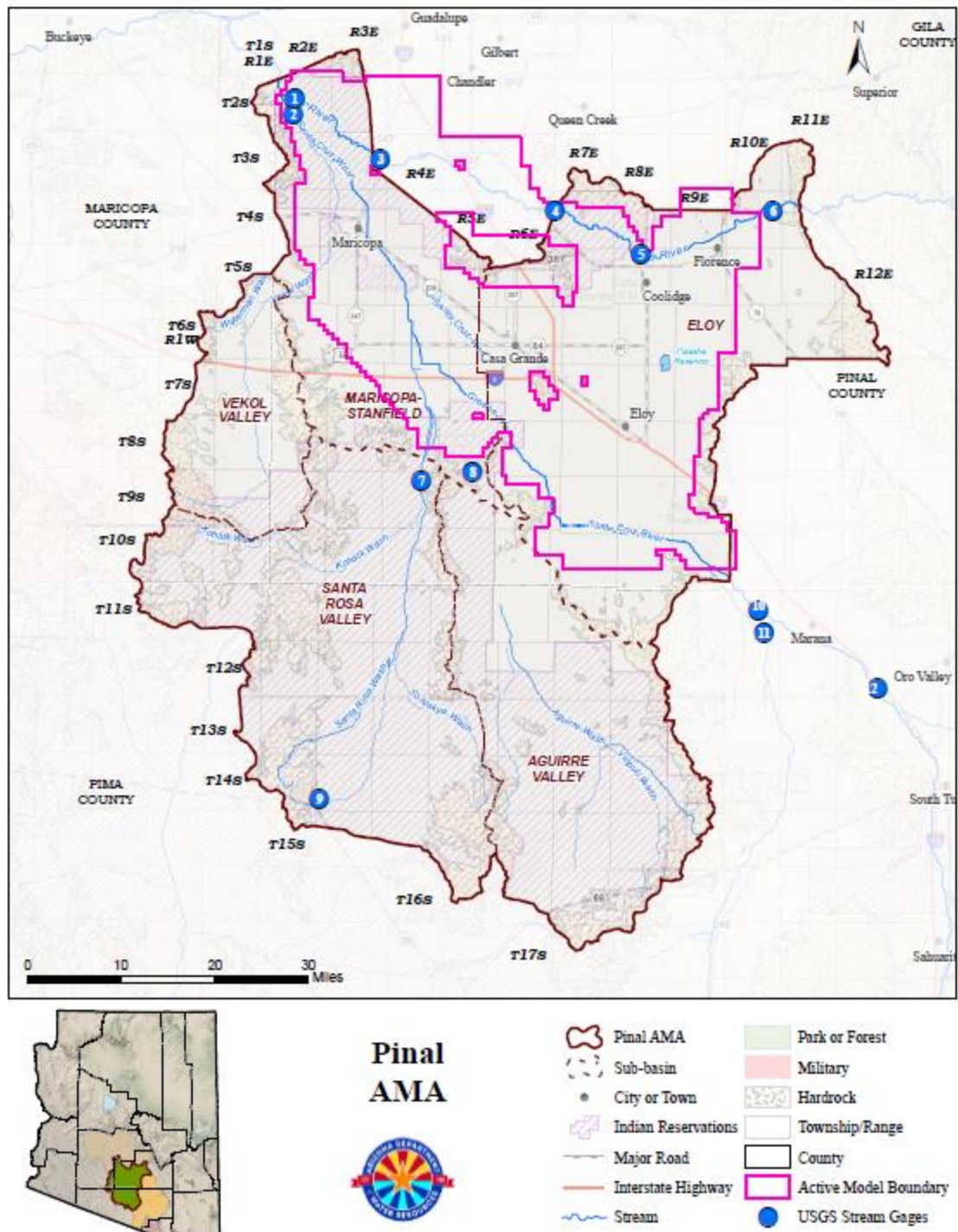
The Gila and Santa Cruz rivers constitute the major surface water drainages within the PAMA. Since Coolidge and Ashurst-Hayden dams were constructed, flow in the Gila River has been largely regulated by upstream reservoir releases and diversions at Ashurst-Hayden Dam. The Gila River is located in the northern portion of the PAMA and flows from east to west. The Santa Cruz River flows northwesterly through the PAMA. The two rivers confluence in the northwest portion of the PAMA (*Figure 2-1*).

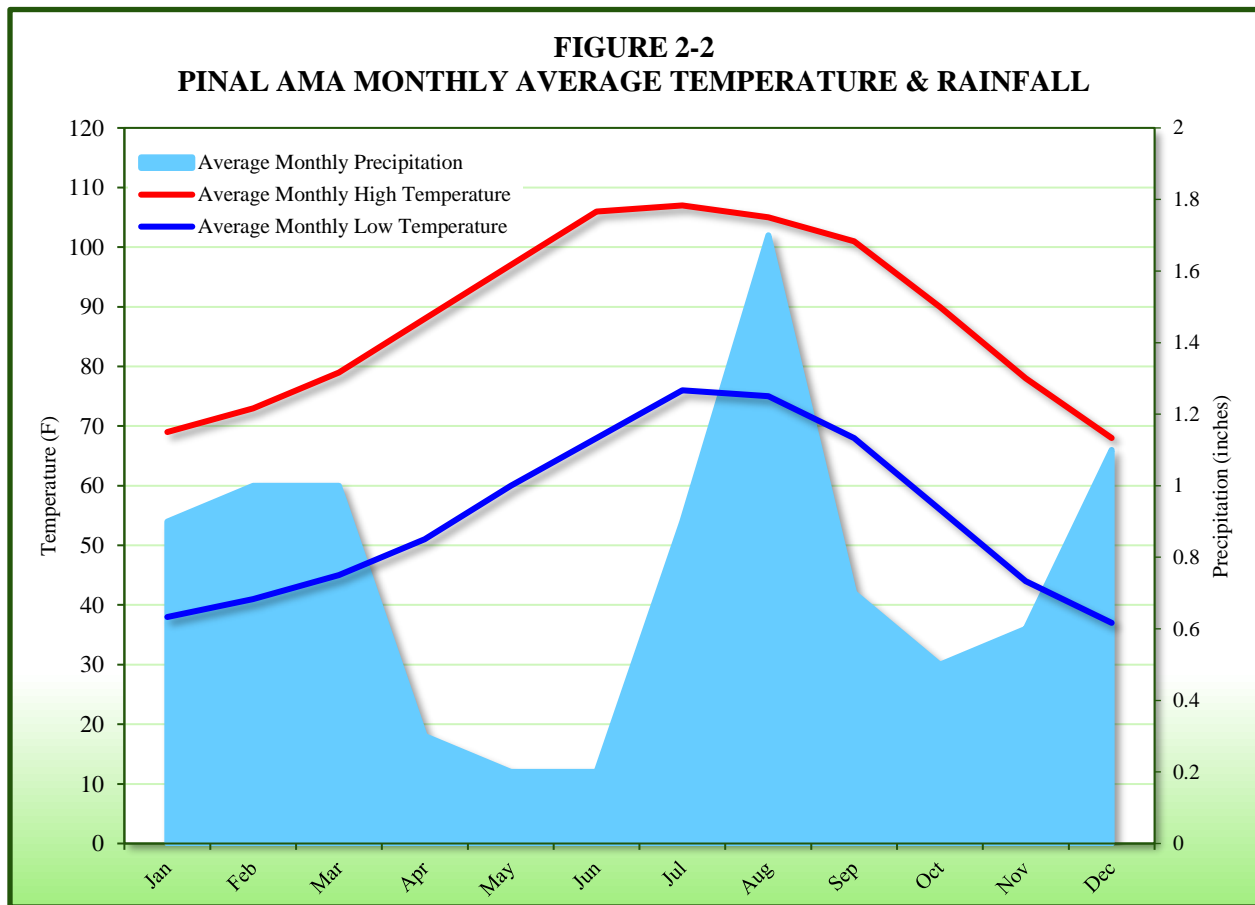
2.2 CLIMATE

The PAMA is located within the Sonoran Desert sub-province of the Basin and Range physiographic province. The climate at the lower elevations is semiarid with sparse vegetation consisting of creosote, mesquite and cacti. Average annual rainfall in the Casa Grande area of the PAMA is about nine inches. In January, the average daily maximum temperature is 67° F and the average daily minimum temperature is 37° F. In July, the average daily maximum temperature is 105° F and the average daily minimum is 76° F (US Climate Data, 2015).

The month of August has the highest annual average precipitation and the month of December has the second highest annual average precipitation (*Figure 2-2*). In the summer, moist air from sources including the Gulf of California, the Pacific Ocean and the Gulf of Mexico reaches the Basin and Range physiographic region of Arizona, including the PAMA, which can result in the formation of thunderstorms (Adams & Cornrie, 1997). These storms, generally occurring in the late afternoon or early evening, may be intense but are usually widely scattered and of short duration. Heavy late summer rains sometimes result from tropical storms moving north along the west coast of Mexico. During the winter precipitation is associated with storms originating in the northern Pacific which move across the continent after intensifying off the West Coast. This precipitation is less intense, of longer duration, and more widespread than during the summer months.

**FIGURE 2-1
PINAL ACTIVE MANAGEMENT AREA**





Source: Weather.com monthly averages for Casa Grande, AZ (Casa Grande, AZ Weather, 2015).

2.3 SURFACE WATER RESOURCES

The main surface water drainages in the PAMA are two ephemeral streams, the Gila River and the Santa Cruz River. The Gila River is located in the northern portion of the AMA, and flows from east to west. Until the late 1800s, the Gila River was perennial throughout the AMA with an estimated 500,000 ac-ft per year flow. Since the construction of Coolidge Dam and Ashurst-Hayden Dam, the flow in the Gila River has been generally regulated by upstream reservoir releases and diversions at Ashurst-Hayden Dam. Gila River releases were reported in annual reports from the San Carlos Irrigation Project (SCIP) beginning in 1930 although diversions began much earlier. Annual diversions from the Gila River by SCIP at Ashurst-Hayden Dam have averaged 232,000 ac-ft per year from 1934 to 2013.

Historically, the Santa Cruz River flowed into the PAMA only during significant flood events. In modern times, a significant portion of the Santa Cruz River flow into the PAMA originates as reclaimed water discharge in the Tucson AMA (TAMA). The estimated volume of both natural stream flow and reclaimed water (originating at two Pima County Regional Wastewater Reclamation Department (PCRWRD) treatment plants in Tucson) entering the PAMA from the TAMA, including tailwater runoff from farms in the vicinity of Marana, has averaged 22,400 ac-ft per year between 1939 and 2014. The reclaimed water portion of that flow has averaged about 3,400 ac-ft per year. However, there have been several years with no flow at the PAMA boundary. In the significant flood year 1983, the estimated inflow at the PAMA

boundary exceeded 184,000 ac-ft. Recent improvements in TAMA wastewater treatment facilities have improved the quality of the reclaimed water discharged, resulting in a higher percentage of the discharged water recharging in the TAMA and reducing or eliminating the flow of water across the TAMA boundary into the PAMA.

Within the PAMA boundary, the reclaimed water generated by the Casa Grande Wastewater Treatment Facility is delivered to various users including a golf course, an electric power generating station, and farmland, with the remainder discharged to the Santa Cruz River bed (Burgess and Niple, 2004). According to the City of Casa Grande website, the plant currently processes approximately six million gallons per day of reclaimed water, and after deliveries are made, approximately 3,500 ac-ft per year is discharged to the North Branch of the Santa Cruz Wash. The City of Casa Grande has obtained water storage permits and facility permits to store reclaimed water at constructed basins and in a designated portion of the Santa Cruz Wash where the reclaimed water is already being discharged. Storing reclaimed water pursuant to these permits will allow the City of Casa Grande to earn long-term storage credits.

The confluence of the Gila and Santa Cruz Rivers is located in the northwestern portion of the PAMA. Vekol Wash, Santa Rosa Wash, and Aguirre Wash drain the southern valleys of the PAMA and flow northward to join the Santa Cruz River upstream from its confluence with the Gila River. McClellan Wash drains the eastern valleys of the PAMA and joins the Santa Cruz River northwest of Picacho. Brady Wash also drains portions of the eastern side of the PAMA and discharges into Picacho Reservoir.

Table 2-1 provides a summary of the US Geological Survey (USGS) stream gages with flow data in and near the PAMA. Figure 2-1 provides the locations of those gages. Due to local terrain and changes in the meandering course of the Santa Cruz River where it enters the PAMA at Red Rock, the installation of a permanent gaging station to measure streamflow into the AMA has not been feasible. The volume of Santa Cruz River flow entering the PAMA is based on measurements at gages along the Santa Cruz River at Cortaro and Trico Roads and are modeled as an outflow from the TAMA Groundwater Flow Model and inflow into the PAMA model area.

Six surface water structures have been constructed in the PAMA: Ashurst-Hayden Diversion Dam, Picacho Reservoir, Link Reservoir, Tat Momolikot Dam, and two reservoirs recently constructed by the Hohokam Irrigation and Drainage District for regulating the flow of Central Arizona Project (CAP) water. Ashurst-Hayden Diversion Dam and Picacho Reservoir are components of SCIP. Picacho Reservoir was designed to regulate canal flow and has a storage capacity of 24,500 ac-ft. Link Reservoir, with a storage capacity of 60 ac-ft, is the terminal reservoir for the CAP in the Maricopa-Stanfield Sub-basin area. Tat Momolikot Dam, designed to control flooding on the Santa Rosa Wash, has a reservoir storage capacity of 373,000 ac-ft. However, the reservoir, Lake St. Clair, is normally dry. The Hohokam East Regulating Reservoir is designed to store approximately 170 ac-ft of CAP water and the Hohokam West Regulating Reservoir, about 120 ac-ft.

TABLE 2-1
USGS STREAM GAGES IN AND NEAR THE PINAL AMA

Map Label	USGS Gage ID	USGS Station Name	Gage Data Records
1	9479500	GILA RIVER NEAR LAVEEN	1940-1995
2	9489000	SANTA CRUZ RIVER NEAR LAVEEN	1940-1955
3	9479350	GILA RIVER NEAR MARICOPA	1995-2015
4	9478350	GILA RIVER NEAR SACATON	1995-1999

Map Label	USGS Gage ID	USGS Station Name	Gage Data Records
5	9477570	GILA RIVER AT ATTAWAY	2002-2009
6	9475500	FLORENCE-CASA GRANDE CANAL NEAR FLORENCE	1984-2015
7	9488500	SANTA ROSA WASH NEAR VAIVA VO	1955-1980
8	9488600	SILVER REEF WASH NEAR CASA GRANDE	1950-1974
9	9487400	QUIJOTOA WASH TRIB. NEAR QUIJOTOA	1963-1975
10	9486520	SANTA CRUZ RIVER AT TRICO RD NEAR MARANA	1989-2015
11	9487250	LOS ROBLES WASH NEAR MARANA	1962-1983
12	9486500	SANTA CRUZ RIVER AT CORTARO	1940-2015

2.4 HYDROLOGIC UNITS AND AQUIFER CHARACTERISTICS

In 2014, ADWR completed an updated groundwater model of the Eloy and Maricopa-Stanfield sub-basins (ADWR, 2014). The groundwater flow model includes updated geology (ADWR, 2010) based on additional data that has been collected since the first PAMA model was developed in the late 1980s (ADWR, 1990), (Wickham & Corkhill, 1989).

There are four hydrologic units within the PAMA. These units are the Upper Alluvial Unit (UAU), the Middle Silt and Clay Unit (MSCU), the Lower Conglomerate Unit (LCU), and the Hydrogeologic Bedrock Unit (HBU). Figure 2-3 includes the location of three cross sections developed during the geology update. (The horizontal axis of each cross section is in meters.) Cross section A – A' (*Figure 2-4*) runs from west to east through the community of Stanfield and just north of the City of Eloy, terminating at the Picacho Mountains. It shows the area known as the Casa Grande Ridge which is a shallow bedrock ridge that extends from the Sacaton Mountains to the north to the Silver Reef Mountains in the south. The shallow depth to bedrock in the area significantly limits groundwater underflow from the Eloy to the Maricopa-Stanfield Sub-basin. Cross section B-B' (*Figure 2-5*) runs north to south through the Maricopa-Stanfield Sub-basin, through the community of Stanfield and terminating near the Viava Hills. It shows the relative thickness of the three water-bearing units in the Maricopa-Stanfield Sub-basin. Cross section C-C' (*Figure 2-6*) runs north to south within the Eloy Sub-basin going through the Town of Coolidge and east of the City of Eloy, terminating at the PAMA boundary between the Silver Bell Mountains and Picacho Peak. It shows the unit thicknesses in the Eloy Sub-basin. The general characteristics of the basin-fill deposits are described below.

FIGURE 2-3
GEOLOGIC CROSS SECTION LOCATIONS

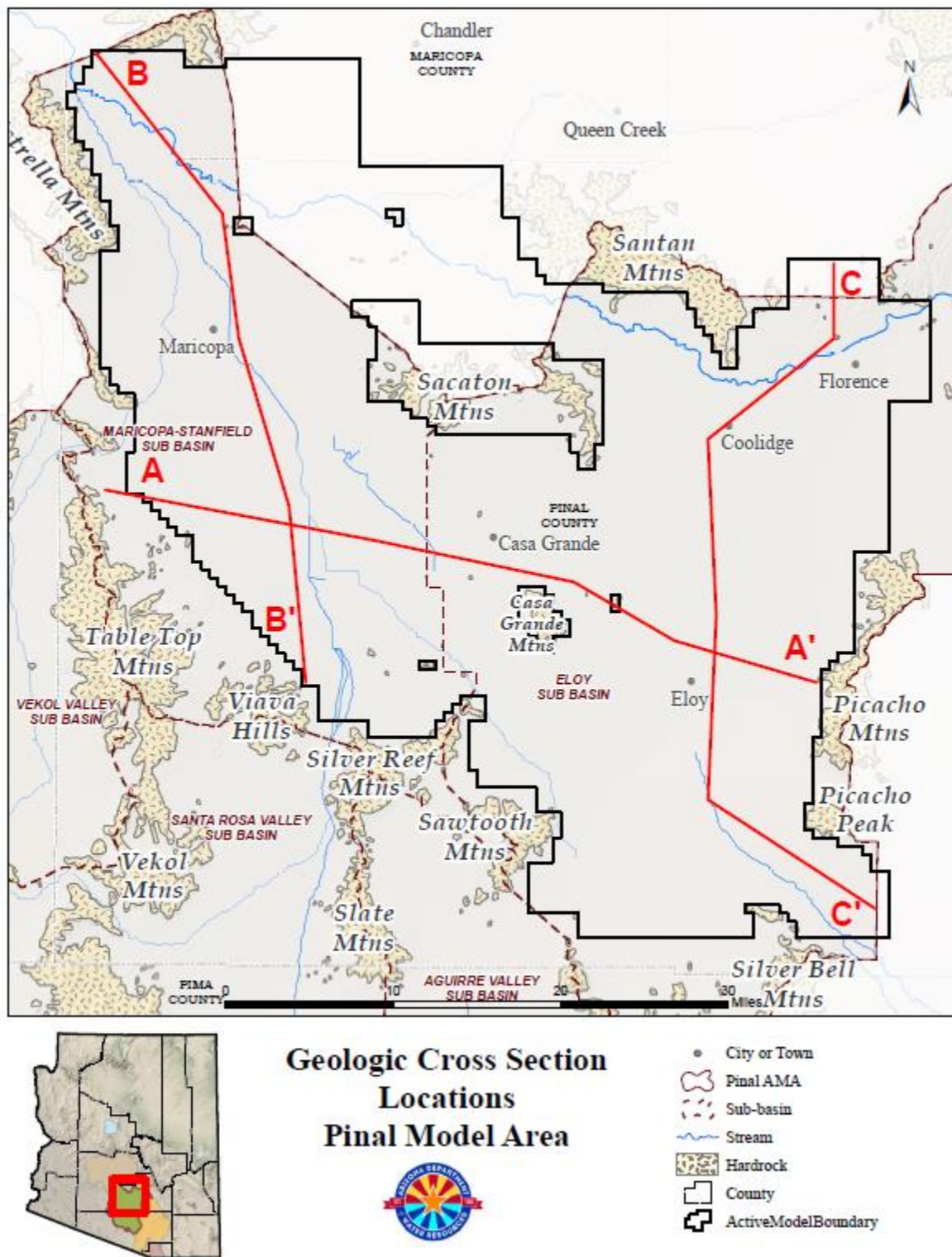


FIGURE 2-4
CROSS SECTION A – A'

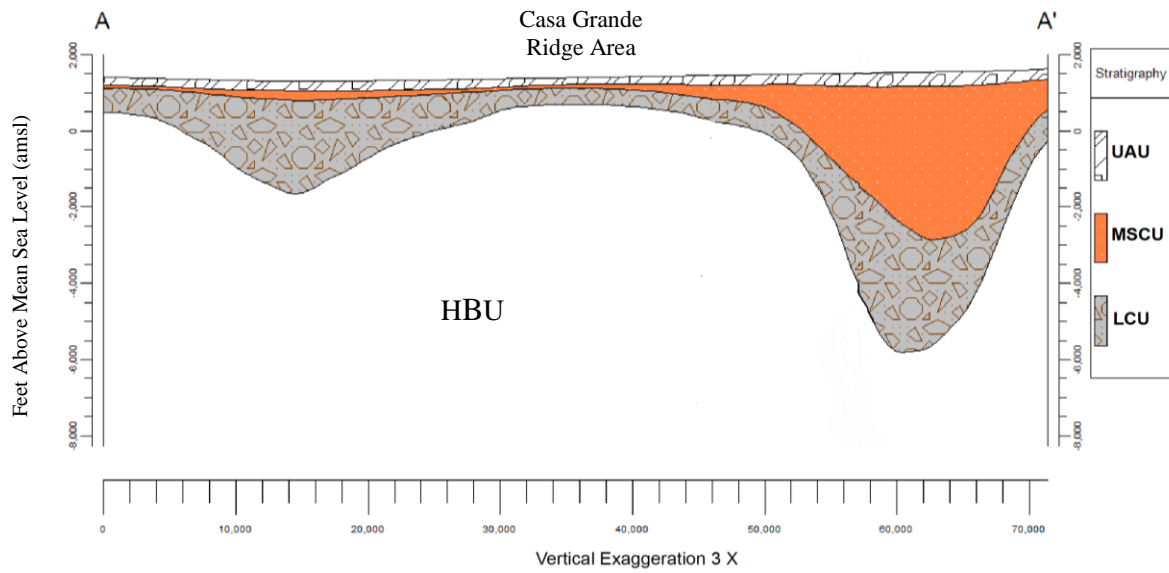


FIGURE 2-5
CROSS SECTION B – B'

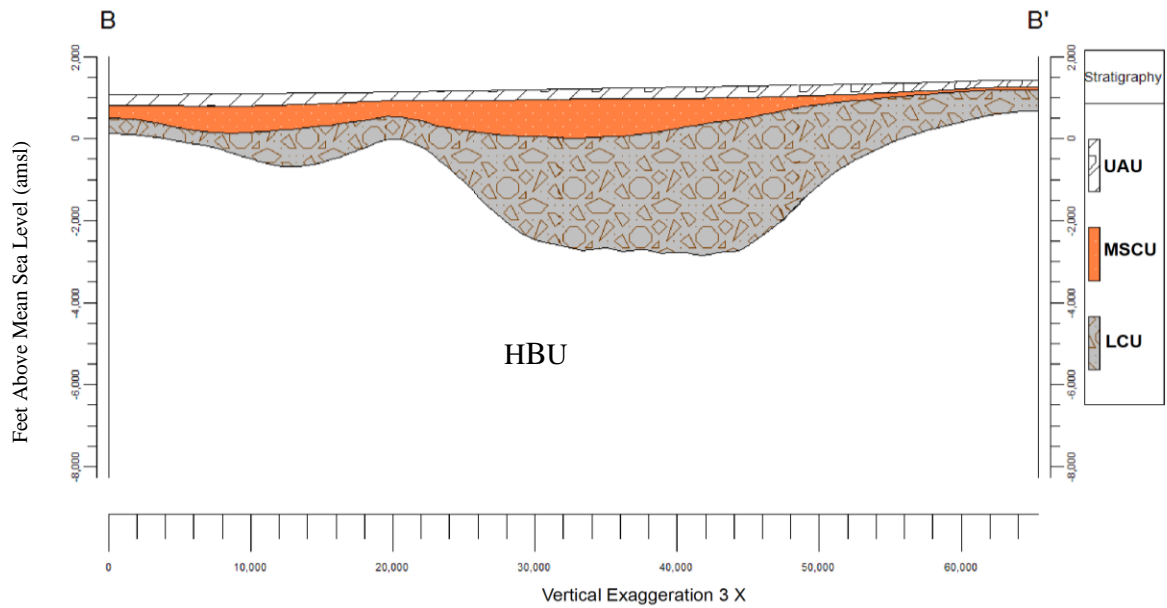
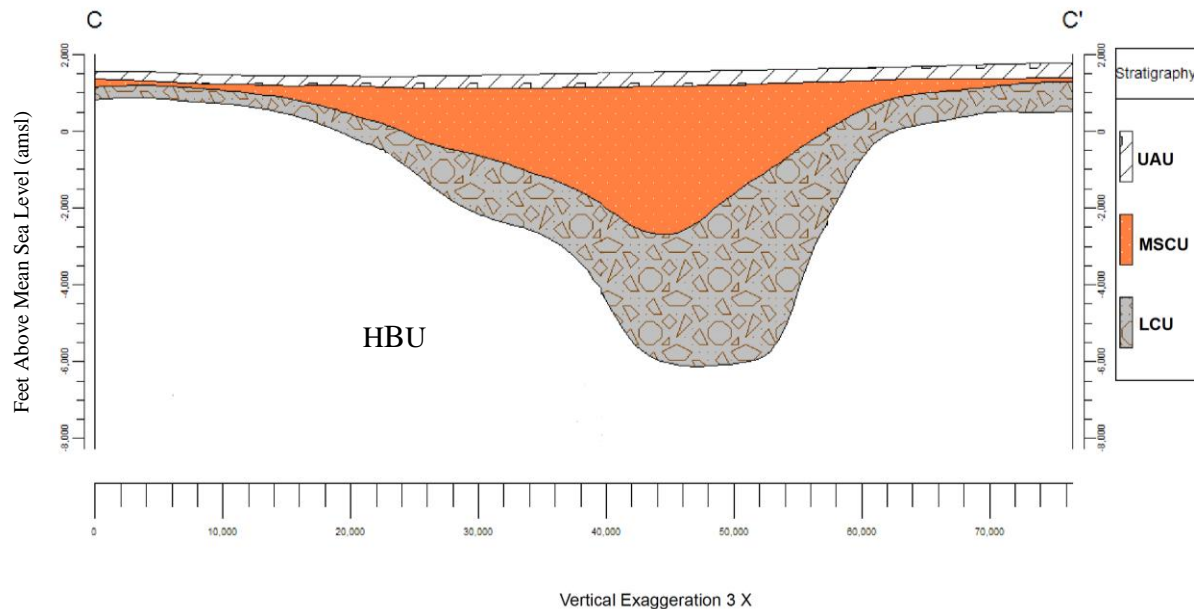


FIGURE 2-6
CROSS SECTION C – C'



2.4.1 Upper Alluvial Unit

The UAU is comprised of unconsolidated to slightly consolidated inter-bedded sand and gravels with some finger grained materials within lenses. Cementation is not predominant. In some areas of the Eloy Sub-basin, a transition zone exists in the lower UAU where coarse alluvial materials are inter-bedded with finer-grained material. The UAU is thicker in the basin centers. The maximum UAU thickness is estimated to be about 450 feet in the Eloy Sub-basin (ADWR, 2014).

2.4.2 Middle Silt and Clay Unit

The MSCU is generally fine-grained consisting mostly of silt, clay and sand. There is little MSCU in the Casa Grande area, along the Gila River corridor, at the basin margins, and in the southeastern portion of the Eloy Sub-basin. As with the UAU, the thickness of the MSCU increases toward the basin centers. The MSCU is more extensive and deeper in the central portion of the Eloy Sub-basin than in the Maricopa-Stanfield Sub-basin. The maximum thickness of the MSCU exceeds 2,800 feet in the central portion of the Eloy Sub-basin (ADWR, 2014).

2.4.3 Lower Conglomerate Unit

The LCU includes semi-consolidated to consolidated coarse-grained conglomerates and other sediments with varying degrees of cementation. The LCU typically overlies impermeable bedrock. There is little or no LCU over the Casa Grande Ridge area. The estimated thickness of the LCU ranges from less than 50 feet to over 8,000 feet. The LCU is thicker in the northwest portion of the PAMA and in the centers of the Maricopa-Stanfield and Eloy sub-basins. The LCU is thickest in the area southwest of the City of Eloy (ADWR, 2014).

2.4.4 Aquifer Characteristics

The designation of the three water bearing units described above and used in the groundwater model was

based on previous work done in central Arizona. W.T. Lee investigated the underground water in the Gila Valley and documented hydrogeologic information for the Gila Valley including geology, wells, water levels and groundwater quality (Lee, 1904). The study area consisted mainly of the shallow groundwater beneath the Gila River Indian Community (GRIC) that straddles the PAMA and the Phoenix AMA (Smith, 1940). Groundwater underflow was also estimated in this study. Additional work was completed in the Eloy area (Smith, 1940), the Santa Cruz Basin (Turner & others, 1943), the Gila River Basin, and adjacent areas (Halpenny & others, 1952). In 1965, W.F Hardt separated the LCU into a local gravel unit and a lower sand and gravel unit. He indicated that where the lower unit was overlain by silt and clay, it was under artesian conditions, and where it was not, it was indistinguishable from the upper sand and gravel unit, and the water was under water table conditions. Prior to significant groundwater development, the movement of groundwater was controlled mainly by the differences in the altitude of the water surface at the extremities of the area; the regional groundwater movement was northwestward from Red Rock and westward along the Gila River. North of the City of Maricopa, the groundwater flowed from the area through the narrow Gila River channel between the Sierra Estrella and the Salt River mountains. Pumping caused cones of depression and shifted the natural flow of groundwater (Hardt & Cattany, 1965).

The mountainous perimeter of what is now the PAMA is composed of predominately volcanic rocks of cretaceous, tertiary and quaternary age and crystalline and metamorphic rocks of pre-Cambrian and later age. The hard rocks of the mountains and bedrock underlying the basin-fill are too impermeable to yield significant water to wells. The alluvial fill is tertiary and quaternary age, generally several hundred feet thick, with more recent alluvium along stream channels. The stream alluvium is not considered a significant or separate aquifer. The western Eloy and eastern Maricopa Stanfield sub-basins are underlain by the Casa Grande Ridge.

The middle silt and clay unit (MSCU) is comprised of a thick series of clays with more permeable sand lenses and stringers underlying the water table aquifer (Halpenny & others, 1952). Near the Casa Grande Ridge, the thickness of the clay unit ranges from 0-200 feet thick and is less productive but yields moderate amounts of water from thin stringers and lenses of highly permeable sand and gravels (Hardt & Cattany, 1965).

In the first half of the 20th century, most irrigation wells withdrew water from within 800 feet of the surface but deeper wells encountered water-bearing beds at greater depths (Halpenny & others, 1952). The UAU is 50 to 600 feet in thickness and has a wide range of well yields (Hardt & Cattany, 1965). Irrigated agriculture has depleted the groundwater from portions of the UAU and created substantial changes to the direction of groundwater underflow between sub-basins. Prior to about 1900, the groundwater system in the PAMA was in approximate dynamic equilibrium. The head differences between deep and shallow wells were negligible or non-existent.

The historic lowering of the water table in the UAU has resulted in perched conditions in certain areas. There are at least three shallow local water zones perched on fine-grained deposits which receive most of their recharge from human activities such as leakage from unlined irrigation canals and percolation from excess irrigation water applied to crops (Hammett & Herther, 1992).

Aquifer parameters for PAMA basin-fill units including hydraulic conductivities (k) and storage values have been estimated and refined during the development of the PAMA Groundwater Flow Model (ADWR, 2014). Initial estimates were fine-tuned during the transient model calibration. For more detail on final calibrated values for horizontal and vertical hydraulic conductivity, specific yield and specific storage and subsidence parameters, see modeling report number 26, "Regional Groundwater Flow Model of the Pinal

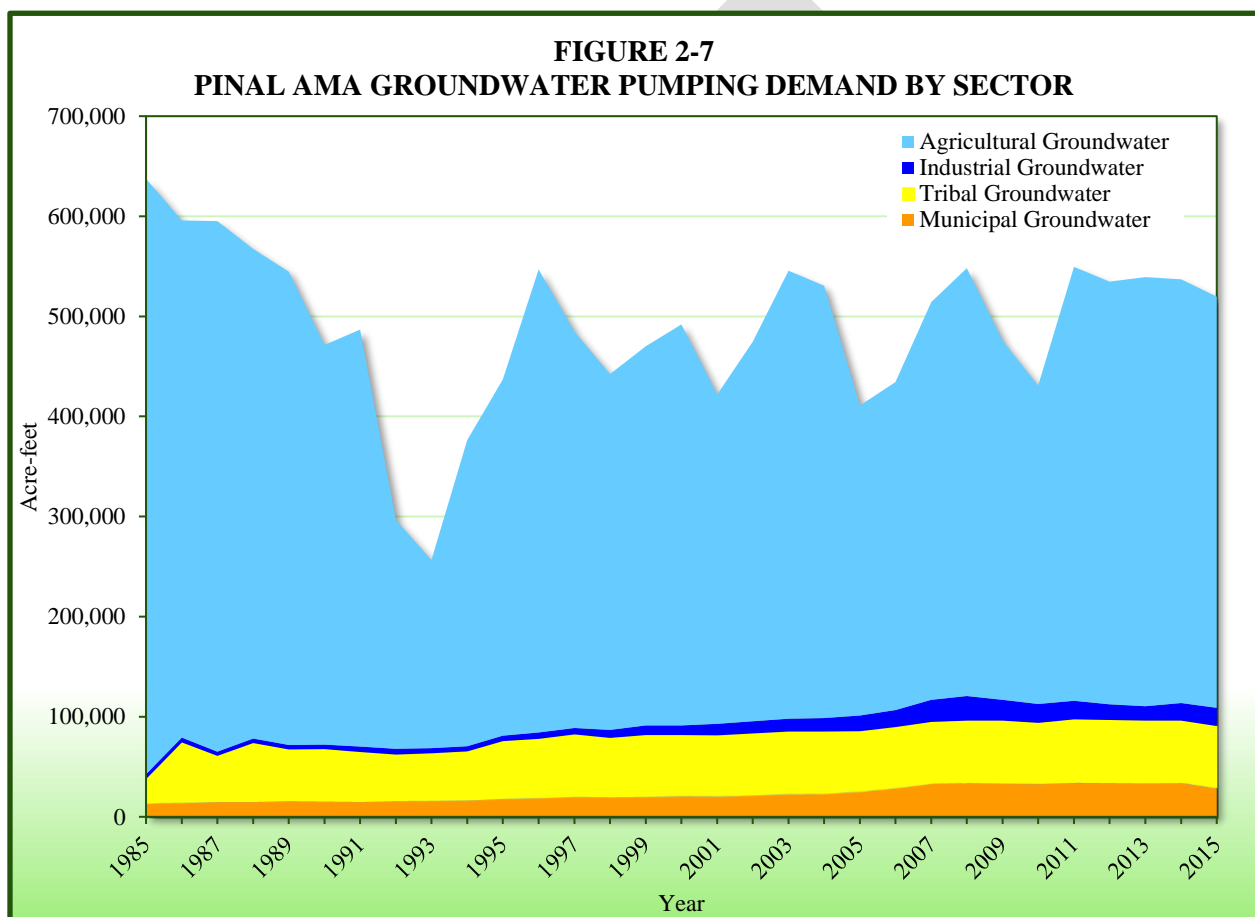
Active Management Area, Arizona,” found at:

http://www.azwater.gov/azdwr/Hydrology/Modeling/Pinal_Home.htm.

2.5 GROUNDWATER RESOURCES

2.5.1 Historical Water Use

Groundwater pumpage in the PAMA is dominated by the agricultural sector. Groundwater pumping has increased since the 1930s, and peaked in 1953 at approximately 1.4 million ac-ft per year, and maintained that relatively high level until the late 1980s. Long-term pumping has greatly exceeded natural recharge. The average annual reported groundwater pumpage for the PAMA from 1985 to 2015 is about 489,000 ac-ft (Figure 2-7). This figure does not include recovery of stored water from recovery wells.



Agricultural groundwater use was over 500,000 ac-ft per year in 1985, 1986 and 1987, but has been less since those years. The lowest volume of groundwater use in the agricultural sector in PAMA occurred in 1993, when significant surface water supplies from the Gila River sharply reduced San Carlos Project pumping and over 230,000 ac-ft of in-lieu CAP water was provided to PAMA farms. In-lieu CAP is CAP water used in lieu of groundwater. CAP water is provided by a water storer who receives credit for the groundwater saved, which can be used by the storer in the future. Municipal groundwater use has increased in the PAMA from about 13,000 ac-ft in 1985, to just over 24,000 ac-ft in 2015. Industrial groundwater use has also increased from about 5,000 ac-ft in 1985 to approximately 18,400 ac-ft in 2015. Tribal groundwater use is primarily related to agricultural activity on tribal land. Tribal groundwater use has also increased,

from about 24,500 ac-ft in 1985 to more than 62,000 ac-ft in 2015. Please note that groundwater usage on tribal land is often estimated because tribal lands have no requirement to report water use to ADWR. See Chapter 3 of this plan for more description of historical water uses by source of supply for each water use sector in the PAMA.

Arizona Agricultural Statistics indicate that less than 15,000 acres were actively farmed (cropped) in Pinal County prior to 1904. The number of cropped acres increased rapidly in the 1930s and peaked in 1952 at 315,400 acres. Cropped acreage fluctuated between 200,000 and 300,000 through the late 1970s and then fell between 150,000 and 250,000 acres since that time. University of Arizona agricultural maps from 1947, 1954, 1963 and 1973 indicate more acres in Pinal County than the Agricultural Statistics, but it is unlikely that all of those acres were cropped in any given year. This may explain why the area covered by the irrigation districts in both sub-basins (186,980 acres in Eloy and 104,303 acres in Maricopa-Stanfield for a total of 291,283 acres) is larger than the total cropped acres listed in the Agricultural Statistics in most years.

Arizona Agricultural Statistics are provided only at the county level and are not broken out by sub-basin. ADWR Irrigation Grandfathered Groundwater Right (IGFR) boundaries, crops observed during field visits by ADWR or USGS staff, and/or remote-sensing based Cropland Data Layer (CDL) information from the USGS indicate that between 192,568 and 206,590 acres were in production in both the Eloy and Maricopa-Stanfield sub-basins between 2010 and 2014. Double cropping has become a common practice resulting in increases in water demand in areas where this is occurring.

2.5.2 Maricopa-Stanfield Sub-basin

Historically, approximately 85 percent of the groundwater withdrawals in the Maricopa-Stanfield Sub-basin are used for agricultural irrigation with the remaining 15 percent used by the municipal and industrial sectors. In the time since ADWR pumping records have become available (1984 – 2015) the percentage of groundwater pumped for agricultural purposes has declined from about 98 percent in 1984 to 85 percent in 2015. Pumping in this sub-basin has increased from 3,300 ac-ft in 1923 to 159,200 ac-ft in 2015. Pumping in the sub-basin peaked in 1953 at almost 550,000 ac-ft. The Ak-Chin Indian Reservation farmed using solely groundwater prior to the availability of CAP water in 1988 and currently farms using CAP water almost exclusively. The acres of agriculture in the sub-basin, based on the University of Arizona irrigation maps, indicate 66,236 acres were cropped in 1947, increasing to 152,924 acres in 1954, and decreasing to 140,608 acres in 1963 with little change through 1973 when the maps indicate 141,319 acres were cropped. Irrigation districts in the sub-basin encompass 104,303 acres. Between 2010 and 2014 between 74,814 and 82,838 acres were cropped each year.

2.5.3 Eloy Sub-basin

Most groundwater withdrawn in the Eloy Sub-basin prior to 1980 was used for agriculture. An estimated 60,000 ac-ft was pumped in 1923. Groundwater withdrawals increased rapidly in the 1930s, and peaked at over 760,000 ac-ft in 1953. Pumping began to decline to about 400,000 ac-ft per year by the time ADWR records became available in 1984. In 1984, agricultural pumping accounted for over 98 percent of the 380,000 ac-ft pumped that year, including the 45,000 ac-ft withdrawn from SCIP wells in the Eloy Sub-basin. Over the next 30 years pumping has decreased to an average of 313,000 ac-ft per year with non-agricultural uses consisting of about 25 percent in 2015. Prior to the economic downturn of 2010 the non-agricultural sectors pumped almost 15 percent of the groundwater in the sub-basin. Agricultural acres in the Eloy Sub-basin, based on the University of Arizona irrigation maps, indicate that 228,936 acres were cropped in 1947, increasing to 276,547 acres cropped in 1954, decreasing slightly to 269,733 acres in 1963

and further decreasing to 244,639 acres in 1973. There are 186,992 acres within irrigation districts in the Eloy Sub-basin. Between 2010 and 2014 cropped acres ranged from 117,754 and 125,799 acres each year.

2.5.4 Groundwater Recharge and Discharge

2.5.4.1 Recharge

Groundwater recharge components in the PAMA include 1) mountain-front, 2) stream recharge 3) underflow, 4) incidental recharge, and 5) artificial recharge. For the purposes of this report, incidental recharge is defined as water that recharges the PAMA's regional aquifer during the course of its use for agricultural, industrial, or municipal purposes. This includes water that is recharged as a result of irrigation activities, and reclaimed water that is released into the Gila or Santa Cruz Rivers or used for irrigation. Artificial recharge is defined as water that is recharged at constructed or managed recharge projects permitted by ADWR.¹

Historically the largest source of natural recharge to the PAMA has been streambed recharge along the Gila and Santa Cruz Rivers and their major tributaries. Most of the mountains surrounding the PAMA are low-relief and mountain-front recharge in the PAMA is fairly limited, estimated to be about 500 ac-ft per year. The Gila River has provided most of the streambed recharge in the PAMA, but the flow is regulated by spills from the Ashurst-Haden dam and varies considerably from year to year. Flow on the Santa Cruz River entering from the TAMA also varies and is a combination of natural flow and reclaimed water released from the wastewater treatment plant operated by Pima County at Trico Road, which is located about 5.5 miles from the PAMA boundary. In recent years (1985 – 2013) recharge along the Santa Cruz River was greater than along the Gila River within the PAMA, but the cumulative recharge from the Gila River during that time exceeded the Santa Cruz River recharge (approximately 1.2 million ac-ft on the Gila River between 1985 - 2013 versus 0.7 million ac-ft on the Santa Cruz River). Both rivers respond to precipitation and runoff events but the volume carried by the Gila River during such events tends to be far greater, accounting for the higher cumulative volume (approximately 63 percent of streambed recharge in the PAMA sub-basins). During the 1993 flood, over 545,000 ac-ft were recharged along the Gila River and about 100,000 ac-ft along the Santa Cruz River. Annual rates of natural incidental recharge and natural discharge from 1985 through 2015 are listed in Table 2-2. Components include canal seepage, lagged agricultural incidental recharge and riparian evapotranspiration. Artificial recharge is not shown because water that is artificially stored underground belongs to the storer (*See Chapter 8 of this plan*).

TABLE 2-2
PINAL AMA RATES OF ANNUAL NET NATURAL RECHARGE (AC-FT/YEAR)

Year	Natural Recharge			Incidental Recharge		Total Natural & Incidental Recharge	Natural Discharge		Total Natural Discharge	Net Natural & Incidental Recharge
	Mountain Front	Stream Channel	GW Inflow	Canal Seepage	Agricultural Recharge - Lagged		Riparian Evapo-transpiration (GW)	GW Outflow		
1985	500	179,173	84,615	109,955	329,274	703,517	3,465	23,155	26,619	676,897
1986	500	43,328	82,378	121,142	284,118	531,466	2,400	21,021	23,421	508,045

¹ A “managed underground storage facility means a facility . . . that is designed and managed to utilize the natural channel of a stream to store water underground pursuant to permits issued under this chapter through artificial and controlled release of water other than surface water naturally present in the stream” A.R.S. § 45-802.01(12). A “constructed underground storage facility means a facility that . . . is designed and constructed to store water underground pursuant to permits issued under this chapter.” A.R.S. § 5-802.01(4).

Year	Natural Recharge			Incidental Recharge		Total Natural & Incidental Recharge	Natural Discharge		Total Natural Discharge	Net Natural & Incidental Recharge
	Mountain Front	Stream Channel	GW Inflow	Canal Seepage	Agricultural Recharge - Lagged		Riparian Evapo-transpiration (GW)	GW Outflow		
1987	500	20,026	84,998	100,050	321,108	526,682	1,917	20,056	21,974	504,708
1988	500	25,059	85,678	118,127	364,521	593,885	1,567	19,037	20,604	573,281
1989	500	17,145	85,454	102,129	423,444	628,671	1,315	18,288	19,603	609,069
1990	500	38,021	83,760	31,809	292,303	446,393	1,307	18,405	19,712	426,681
1991	500	42,700	83,981	70,361	291,830	489,372	1,390	17,261	18,651	470,721
1992	500	157,597	82,423	84,814	257,661	582,995	1,940	19,037	20,977	562,017
1993	500	645,532	87,720	92,644	254,935	1,081,330	11,989	27,494	39,483	1,041,847
1994	500	18,227	89,091	108,531	359,029	575,378	2,661	22,899	25,560	549,817
1995	500	85,969	88,211	113,440	402,930	691,051	2,517	21,730	24,247	666,804
1996	500	16,529	89,074	132,522	459,941	698,565	1,938	20,193	22,132	676,433
1997	500	5,624	87,481	80,358	427,065	601,029	1,651	19,285	20,936	580,093
1998	500	32,413	85,124	90,156	381,572	589,765	1,545	18,377	19,922	569,843
1999	500	15,886	83,928	59,788	354,118	514,220	1,464	17,320	18,784	495,436
2000	500	50,373	84,429	45,377	379,889	560,568	1,695	17,347	19,041	541,527
2001	500	5,309	80,688	72,494	382,539	541,530	1,430	16,378	17,809	523,721
2002	500	13,971	83,174	45,234	406,396	549,277	1,512	16,514	18,026	531,251
2003	500	21,807	82,284	33,108	397,842	535,541	1,582	16,044	17,626	517,915
2004	500	27,934	84,845	34,884	379,110	527,274	1,672	16,049	17,720	509,554
2005	500	57,383	81,115	86,850	366,281	592,128	1,647	15,313	16,960	575,168
2006	500	131,579	80,699	85,278	373,279	671,335	2,383	16,286	18,669	652,665
2007	500	39,056	79,335	81,359	427,996	628,245	2,094	15,633	17,727	610,518
2008	500	35,770	81,881	102,023	437,411	657,585	1,988	15,862	17,850	639,734
2009	500	14,573	81,046	70,274	389,454	555,847	1,855	15,178	17,033	538,813
2010	500	68,849	75,022	73,527	311,757	529,655	1,857	14,747	16,603	513,051
2011	500	22,839	75,153	58,531	320,785	477,808	1,724	14,212	15,936	461,872
2012	500	18,260	75,223	31,437	304,811	430,231	1,640	13,702	15,342	414,889
2013	500	26,023	76,891	35,005	292,431	430,850	1,641	13,509	15,149	415,701
2014	500	21,263	75,596	58,968	336,456	492,783	1,638	13,528	15,166	477,618
2015	500	12,226	75,343	61,788	319,643	469,501	1,578	13,185	14,762	454,739

According to the USGS (<http://water.usgs.gov/wsc/glossary.html#G>) underflow can be considered groundwater outflow from an area (a model, a basin, an aquifer) into another area that occurs within alluvial material that isn't measured at a stream gaging station. Underflow into the PAMA moves northwest between South Mountain and the Estrellas at about 16,300 ac-ft per year and to the north between the Santans and the Tortolitas. Estimated groundwater underflow is about 3,500 ac-ft per year north of the Town of Florence.

Groundwater underflow enters the PAMA hydrologic model area between the Silverbell Mountains and Picacho Peak, between Picacho Peak and the Picacho Mountains, between the Picacho Mountains and the Cactus Forest area, between the West Silverbell Mountains and the Aguirre Valley area, in the Santa Rosa and Vekol Wash areas, and from the East Salt River Valley Sub-basin in the Chandler area southeast of South Mountain. The total underflow entering the PAMA from known sources outside of the PAMA is between about 45,000 and 55,000 ac-ft per year.

Incidental recharge is defined as water that recharges the regional aquifer during the course of its use for agricultural, industrial, or municipal purposes. On average, incidental recharge is responsible for more than 90 percent of the total estimated recharge to the groundwater system in the PAMA model area. Components include agricultural recharge, canal recharge, urban irrigation recharge, artificial lake recharge, artificial recharge and reclaimed water recharge.

The PAMA has an agricultural dominated economy. Consequently, agricultural incidental recharge is a large and important source of water to the PAMA regional aquifer. Agricultural incidental recharge represents water returned to the regional aquifer when water used for irrigation percolates below the plant root zone rather than being utilized by consumptive use or evapotranspiration. Agricultural incidental recharge is generally estimated to be the product of the total agricultural water use and the irrigation inefficiency (1 - irrigation efficiency). The irrigation efficiency is defined to be the ratio of the total irrigation requirement to the total amount of water applied.

In the PAMA groundwater model the volume of agricultural incidental recharge was estimated based on irrigation maps from 1947, 1954, 1963 and 1973. Later, the agricultural incidental recharge was distributed based on the aerial extent of irrigation districts, tribal land and non-district farming areas with use estimates based primarily on the Arizona Agricultural Statistics. In 2013 and 2014, the USGS Arizona Water Science Center conducted a field investigation of the PAMA and mapped out the location of fields and noted the crop types and irrigation methods. In years where a field was visited by USGS staff, the crop observed was used to estimate water applied and the amount that would be incidentally recharged. The same field boundaries were compared with the USGS satellite-based CDL imagery to obtain information on what was likely being grown in other years in which there was no field visit to better estimate potential agricultural recharge after 2009 (USGS, 2015).

Water levels declined rapidly as a result of significantly increased pumping from the 1940s through the 1970s resulting in depths to water exceeding 200 feet in many parts of the Eloy and Maricopa-Stanfield sub-basins, with some depths to water as much as 350 feet in the southwest section of the Maricopa-Stanfield Sub-basin. Due to the deep water tables and slow seepage of agricultural incidental recharge percolating through the zone, a lag time was applied in the PAMA model to improve calibration. The lag time was estimated to be between 15 and 20 years. It is important to note that water traveling through the unsaturated zone is not yet able to be measured as part of the total water in storage.

Another type of incidental recharge in the PAMA is the seepage from the canal system including seepage through the CAP main aqueduct and laterals and the SCIP main canal and laterals. An estimated 1,710 ac-ft per year seeps through the CAP main aqueduct (ADWR, 2014). Based on SCIP annual reports, the unlined SCIP canals lose between 30 and 50 percent of the water conveyed in them. The estimated seepage varies from year to year depending on the total water diverted and pumped. The estimated average SCIP canal seepage between 1985 and 2014 was approximately 110,000 ac-ft per year.

Additionally, there are small amounts of other incidental recharge in the PAMA including seepage from the Picacho Reservoir and urban irrigation recharge from golf courses, parks, and other areas where urban flood irrigation water is applied. Recharge is also applied at permitted underground storage facilities (USFs), the largest being the Casa Grande Wastewater Treatment plant which discharges treated reclaimed water into a reach of the dry Santa Cruz River channel. Between 1985 and 2013 an average of 2,100 ac-ft per year was recharged at USFs in the PAMA. The volume has increased in more recent years with the addition of new facilities and the increased reclaimed water produced at the wastewater treatment plant.

2.6 GROUNDWATER CONDITIONS

Groundwater conditions in an aquifer can be monitored by collection of water level measurements from wells located throughout the PAMA. The water level in an aquifer reflects the cumulative impacts of inflow and outflow stresses that have been applied to the aquifer. Groundwater level measurements also provide important information on long and short-term water level trends and on aquifer storage changes. Water level data have been collected from wells within the PAMA since the 1900s (Lee, 1904).

The ADWR Hydrology Division's Field Services Unit collects water level data using both conventional field methods (electric sounders or steel tapes) and pressure transducers at automated sites. A selected group of wells, called index wells, are measured annually to monitor on-going groundwater conditions. There are 188 index wells in the PAMA which ADWR measures regularly. However, index wells cannot always be measured for various reasons. About 165 water levels per year were collected between 2000 and 2013 in years when only index wells were measured. In addition to the annual index well data, ADWR also conducts AMA-wide water level surveys, where water levels are measured in as many wells as possible. AMA-wide water level surveys completed in 2003-2004, 2007-2008 and 2013-2014 resulted in 1,196, 1,124, and 1,073 water level measurements collected in the PAMA, respectively. Water level changes over the period 2003 to 2013 are shown in Figure 2-8.

2.6.1 Water Level Trends 1900-2013

Water levels declined significantly in both the Eloy and Maricopa-Stanfield sub-basins over the years of significant groundwater development (since 1940) and were at the lowest in the mid-1970s. In most areas of the PAMA, water levels rose in the 1980s and beyond as a result of conservation efforts and the introduction and increased use of CAP water and other surface water; these sources replaced the use of groundwater pumping to meet agricultural irrigation demands. Some of the increased water levels do not correspond to actual increases in overall aquifer storage, but rather are a result of the lag in agricultural incidental recharge and the delayed release of groundwater from interbedded clay units within the thick MSCU that has occurred due to land subsidence.

As pumping volumes increased from agriculture, large vertical hydraulic gradients have developed between aquifer units in many parts of the Maricopa-Stanfield and Eloy sub-basins where fine-grained sediments restrict vertical groundwater flow. The depths to water encountered in nearby wells screened within different hydrologic units can often vary by hundreds of feet. For many of the wells in the PAMA, construction information is unknown and/or the perforations span multiple aquifer units, so the observed water level is a "composite" or blend of water levels from several aquifers instead of one specific aquifer unit. There are also areas where shallow groundwater is perched within the uppermost layer with unsaturated layers below, corresponding to cascading water encountered during visits to the wells.

Figure 2-9 provides locations of 19 hydrograph well locations (*Figures 2-10 through 2-15*) within the Eloy and Maricopa-Stanfield sub-basins, listed in Table 2-3. Hydrograph locations were selected to provide examples of trends within each layer of each sub-basin and are from wells with the longest period of record and/or most measurements and to provide a good spatial distribution. They are grouped by sub-basin and layer (aquifer unit). Each hydrograph shows the water level elevation above mean sea level (amsl).

In the pre-development period, depths to water were shallow (15 to 142 feet) with greater depths observed in the southeastern portion of the Eloy Sub-basin and the southern portion of the Maricopa-Stanfield Sub-basin. Groundwater generally flowed in a northwesterly direction from southeast of the City of Eloy through the cities of Casa Grande and Maricopa towards the gap between South Mountain and the Sierra Estrella

Mountains, and from east to west generally following the Gila River flow direction. Over the years, the largest water level declines occurred in the southwest portion of the Maricopa-Stanfield Sub-basin. The UAU and MSCU aquifers were dewatered along basin margins, and a steep hydraulic gradient developed west of the Casa Grande Ridge area. Vertical hydraulic gradients developed between aquifers since late 1940s, and groundwater flow direction reversed in the Maricopa-Stanfield Sub-basin. By 1976, depths to water ranged from 45 to 708 feet. Since the 1970s water levels have recovered or stabilized in many areas due to decreased pumping and the introduction of CAP water. In 2013, measured depths to water ranged from 32 to 672 feet.

Trends in layer-specific and sub-basin specific water levels can be analyzed using point measurements, or from the interpolated surfaces derived from measurements or from groundwater model simulated heads. The PAMA groundwater model also provides a good estimate of which areas have been dewatered, resulting in 'dry' cells. The simulated depths to water and water level elevations from the model provides a comprehensive assessment of the trends over time. The PAMA model report (ADWR, 2014) provides additional information on the water level trends.

TABLE 2-3
PINAL AMA HYDROGRAPH WELL LOCATIONS

Sub-Basin	Model Layer	Local ID	Site ID	Registry Number	First Date Measurement	Last Date Measurement
Eloy	1	D-04-10 30BDD	330311111214201	605530	2/6/1952	1/21/2015
		D-06-08 18CDD2	325339111333001	605546	11/7/1984	11/15/2012
		D-08-07 09ADD1	324430111371501		3/24/1941	11/13/2015
		D-08-08 07DDD1	324405111330101		8/19/1941	11/18/2015
		D-10-09 10AAD1	323414111235001	620611	12/6/1955	1/14/2015
	2	D-06-09 29BBA4	325243111264001		2/18/1953	11/14/2014
		D-09-08 20ADD1	323731111320201	620899	9/28/1949	11/13/2015
		D-10-07 08AAA	323442111392101	618271	4/26/1940	11/10/2015
	3	D-05-07W13CAD	325908111355701	608906	9/29/1947	11/10/2014
		D-06-06 07AAA3	325520111452901	604209	1/25/1960	11/10/2014
		D-06-09N04DDD	325617111244801		1/1/1986	11/14/2014
Maricopa-Stanfield	1	D-04-03 35DDD	330147112005001	612706	3/8/1950	11/12/2014
		D-06-05 09ADD	325502111493601		9/26/1940	11/10/2014
	2	D-03-02 23ADD	330914112065801		12/22/1982	11/18/2003
		D-05-02 36BAD	325656112064801		2/2/1951	9/30/2015
		D-05-03 25ADD	325746111595201		12/1/1947	11/12/2014
		D-05-03 29BCC1	325748112045101	615354	2/22/1958	12/17/2013
	3	D-06-04 22CDD	325246111551601	605057	2/21/1945	11/20/1998
		D-07-04 22DDD	324750111554601	626457	1/14/1958	12/17/1985

2.6.2 Maricopa-Stanfield Sub-basin

Following several decades of intensive pumpage and declining water levels, Maricopa-Stanfield Sub-basin water levels began to stabilize in the late 1980s and steadily increase from the 1990s to 2013. Within the sub-basin, 153 sites were measured in both 2007 and 2013. Changes in the water level elevation ranged between -181 to +97 with an average of +8.1 feet higher elevation (rising +1.35 feet/year over a six-year period). At 46 locations the water levels dropped (became deeper) and at 108 locations the water level rose (became shallower). The most significant rises occurred in wells screened in the UAU averaging about +16 feet. Water levels in wells screened in the MSCU and LCU increased an average of +8 feet and +5 feet,

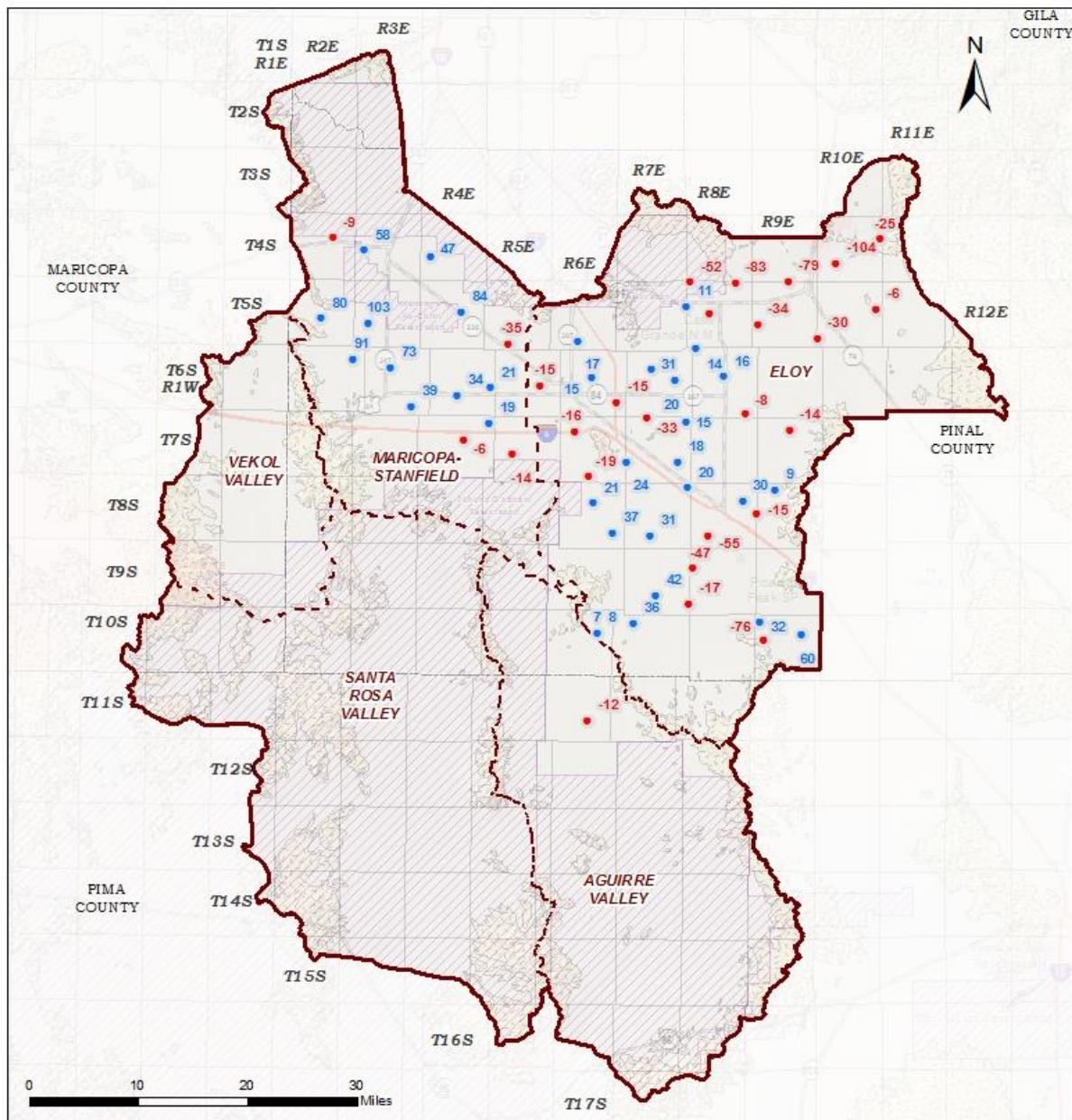
respectively. Some locations are screened across multiple hydrologic units and their water level information represents a combination of the layer-specific levels so it is more difficult to interpret the associated water levels and changes over time at those locations, but they also indicate a similar trend of rising water level elevations in the sub-basin.

The water level elevations were lowest, with maximum depths to water in the mid-1970s, prior to the designation of the PAMA; water levels then began to increase. Interpolated depths to water using all the measurements from both sweeps indicate an average increase of 4.4 feet/year between 1976 and 2013 in the upper layer. The depths to water are still greater than in predevelopment but have recovered significantly in the last few decades.

2.6.3 Eloy Sub-basin

In the Eloy Sub-basin, groundwater responses to pumping varied from north to south. Water levels in the northern part of the sub-basin declined less than in the southern part. In the southern part of the Eloy Sub-basin, water levels declined much more in the MSCU and LCU than in the UAU. Noticeable vertical hydraulic gradients developed between the UAU and MSCU/LCU starting in the late 1960s and became more significant as development progressed. There was a delay of about 20 years for the vertical hydraulic gradient to become apparent between the aquifer systems in the southern part of the Eloy Sub-basin compared to the southwestern part of the Maricopa-Stanfield Sub-basin. It is possible that water released from extensive aquifer compaction observed in the southern part of the Eloy Sub-basin contributed to the delay of development of vertical gradients in that area.

FIGURE 2-8
WATER LEVEL CHANGE

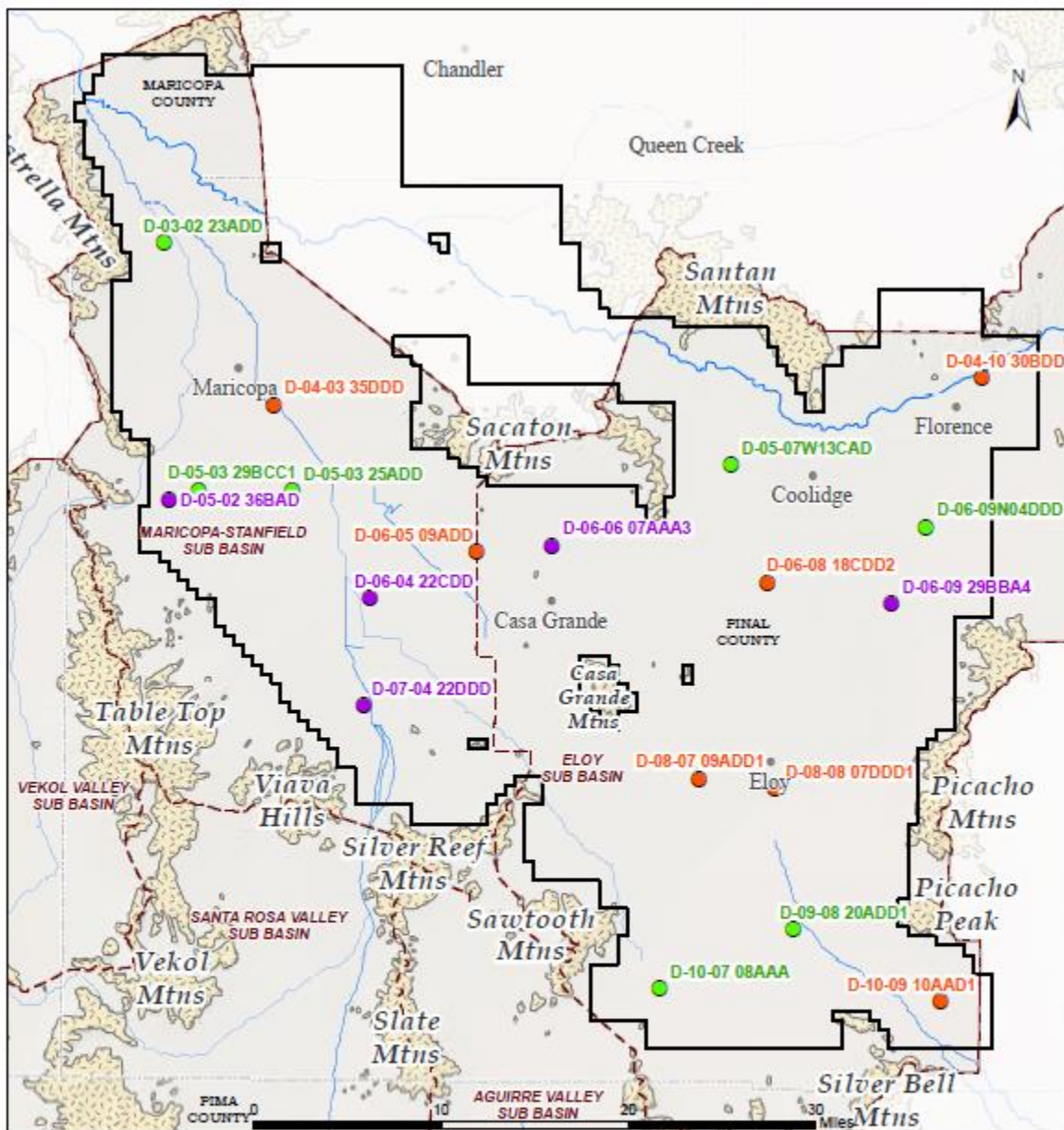


- | | | | |
|--|---------------------|--|-----------------|
| | Pinal AMA | | Park or Forest |
| | Sub-basin | | Military |
| | City or Town | | Hardrock |
| | Indian Reservations | | Township/Range |
| | Major Road | | Positive Change |
| | Interstate Highway | | Negative Change |
| | Stream | | |

Water Level Change
2003-2013
Pinal AMA



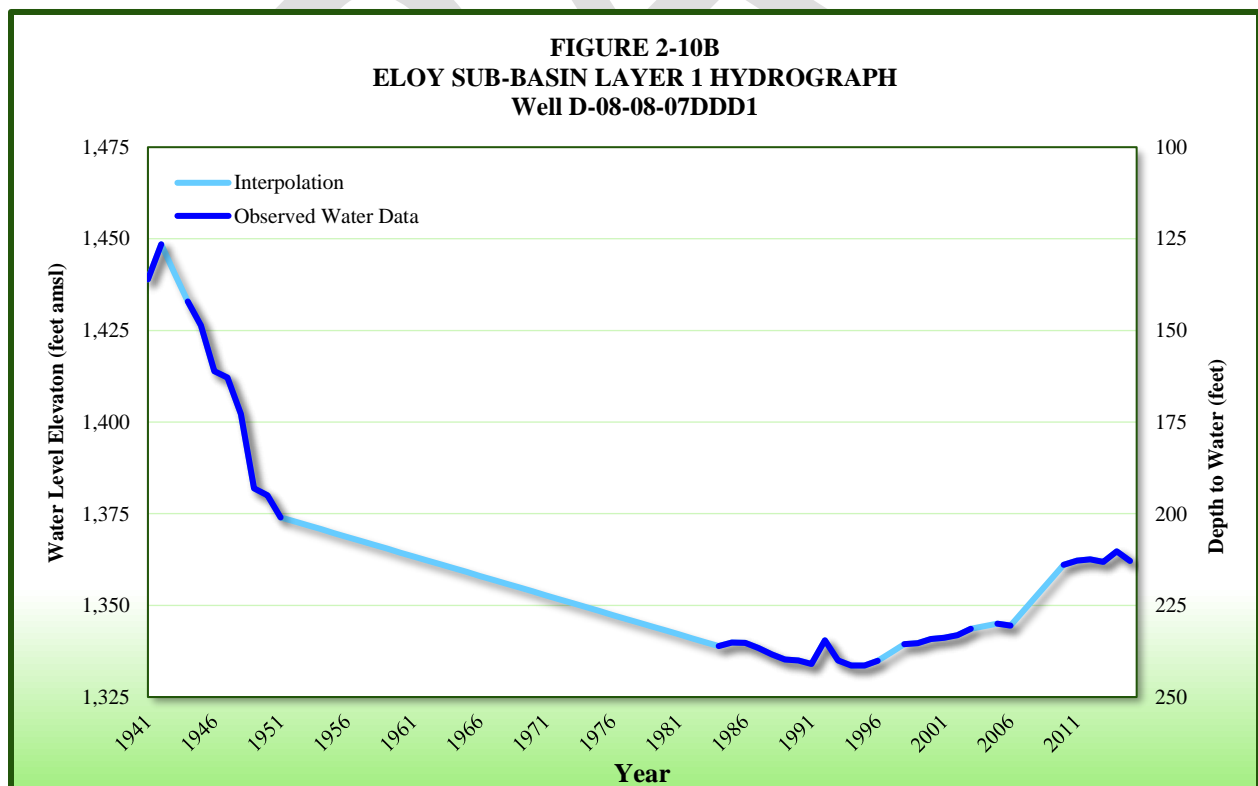
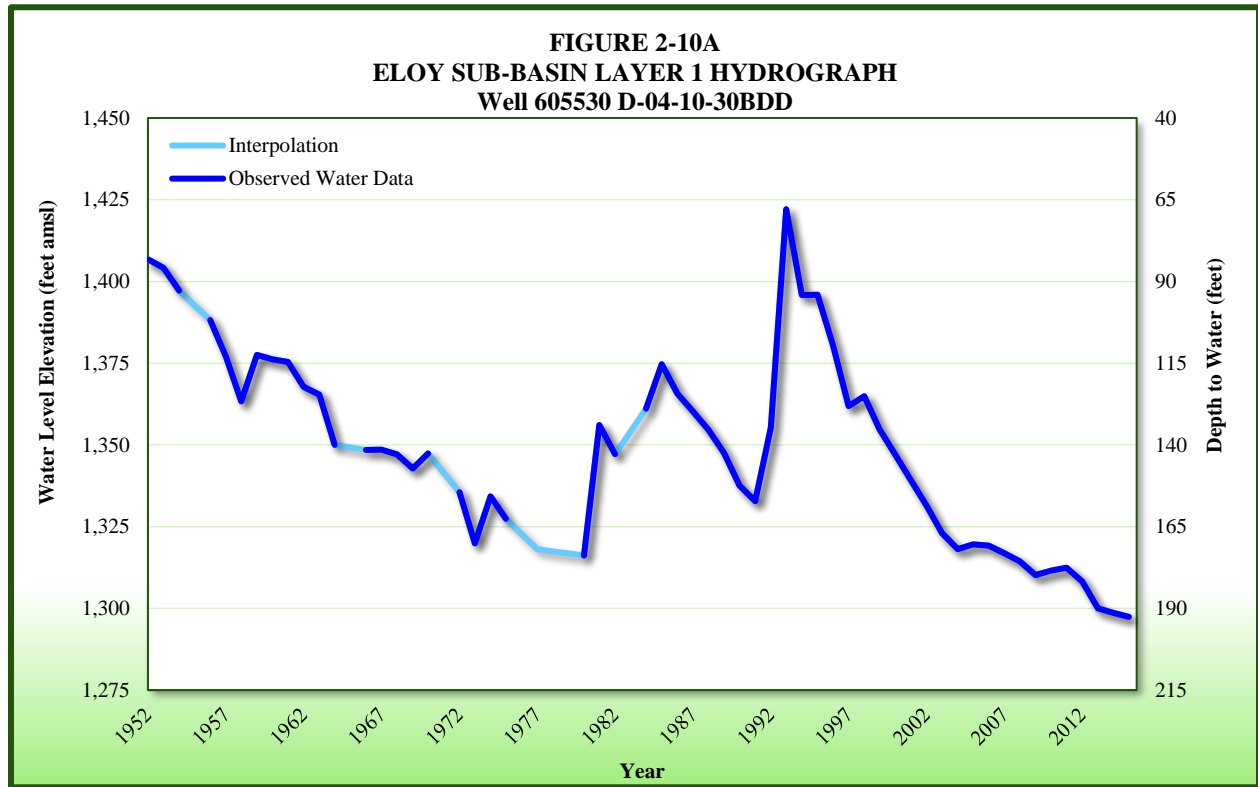
**FIGURE 2-9
HYDROGRAPH LOCATIONS**

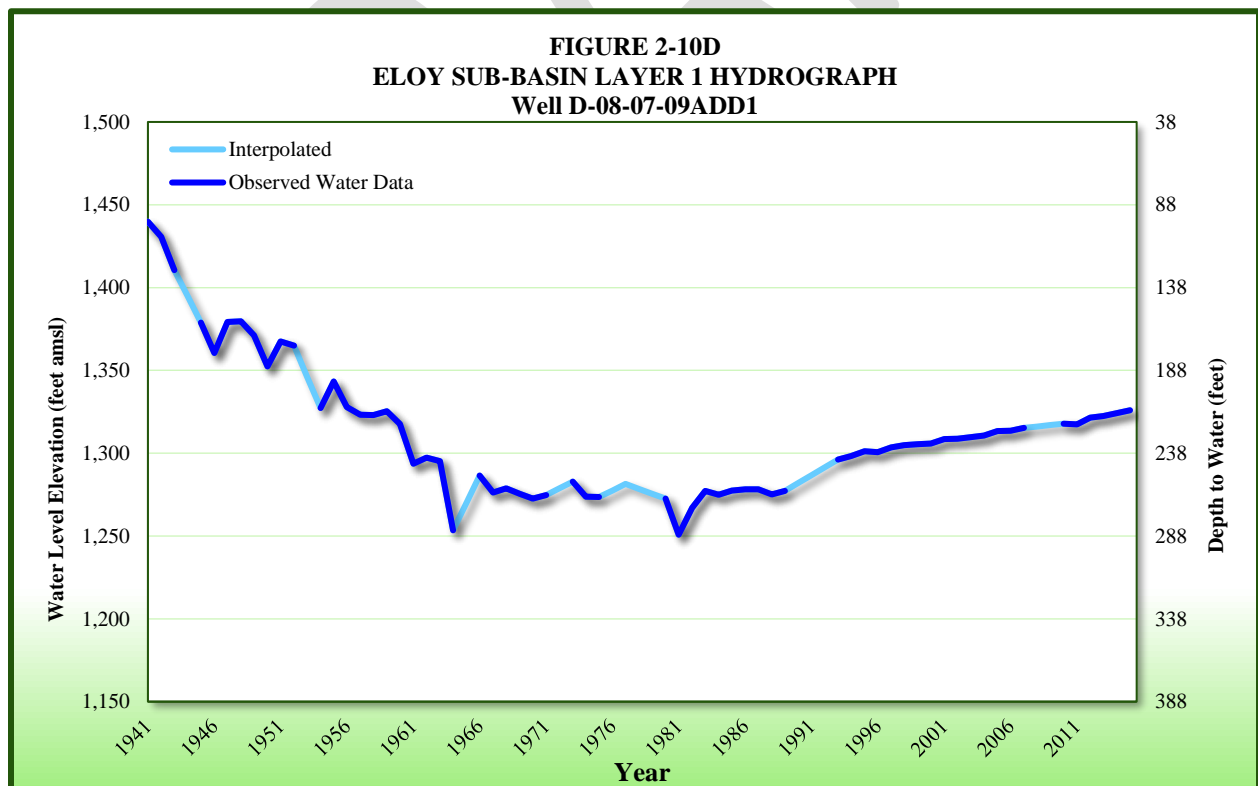
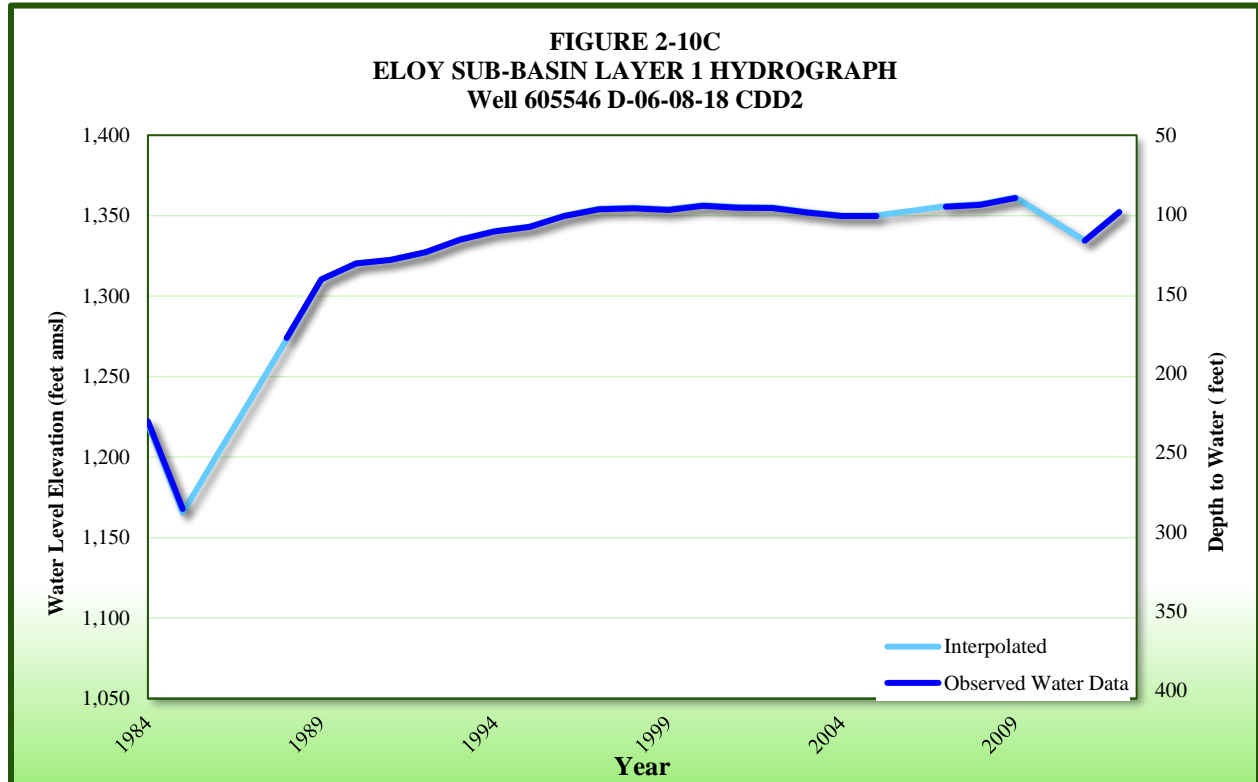


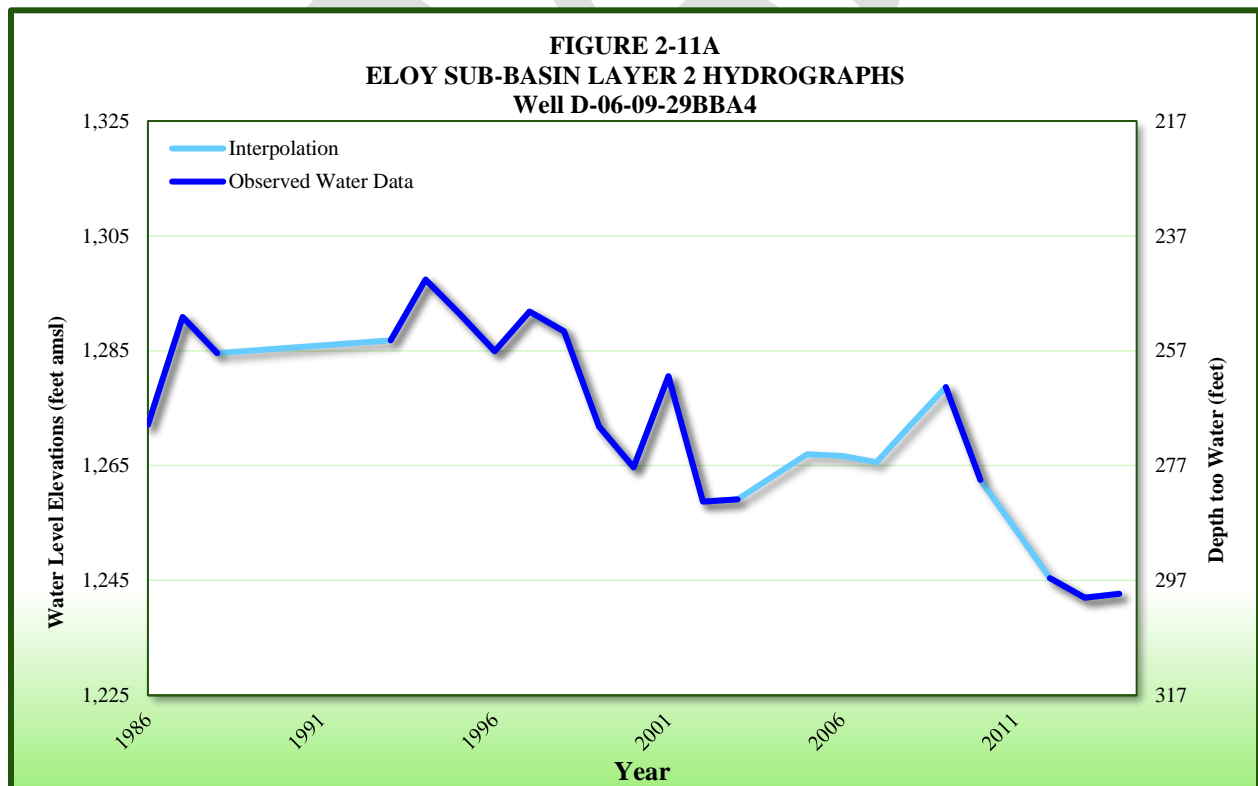
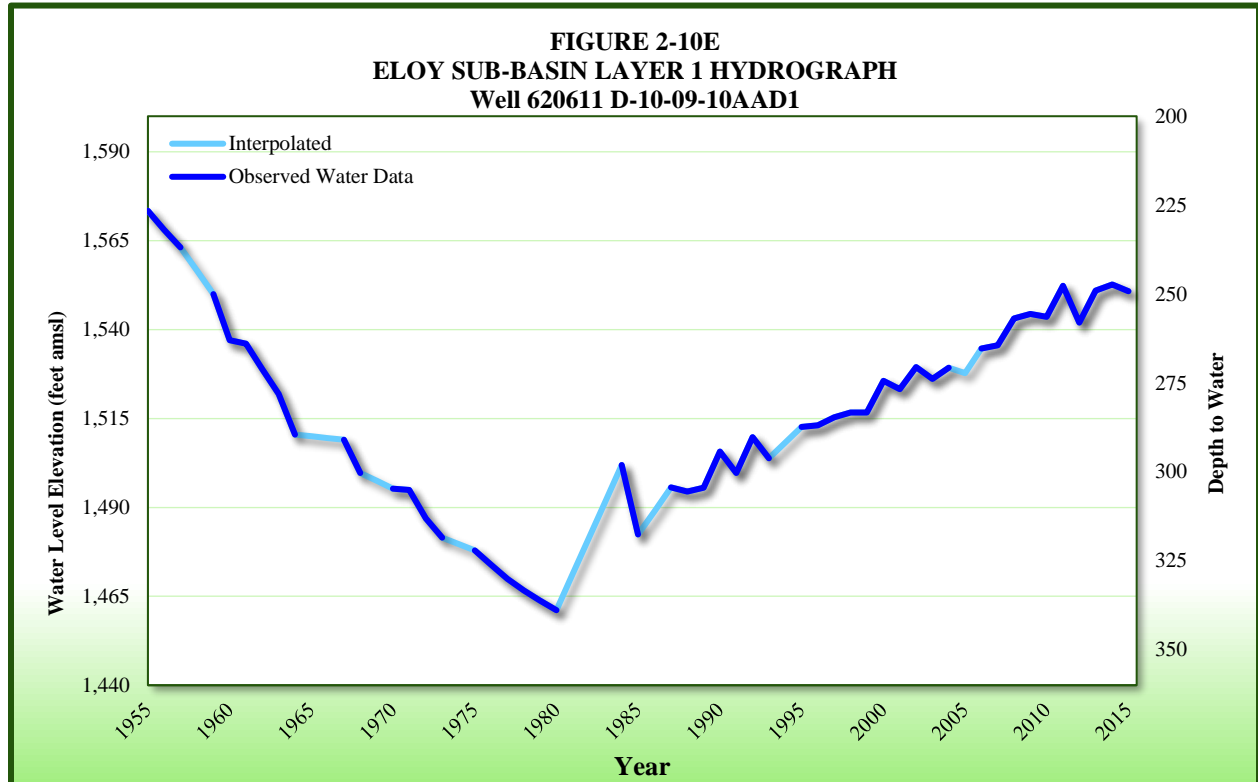
**Select Hydrograph
Locations
Pinal Model Area**

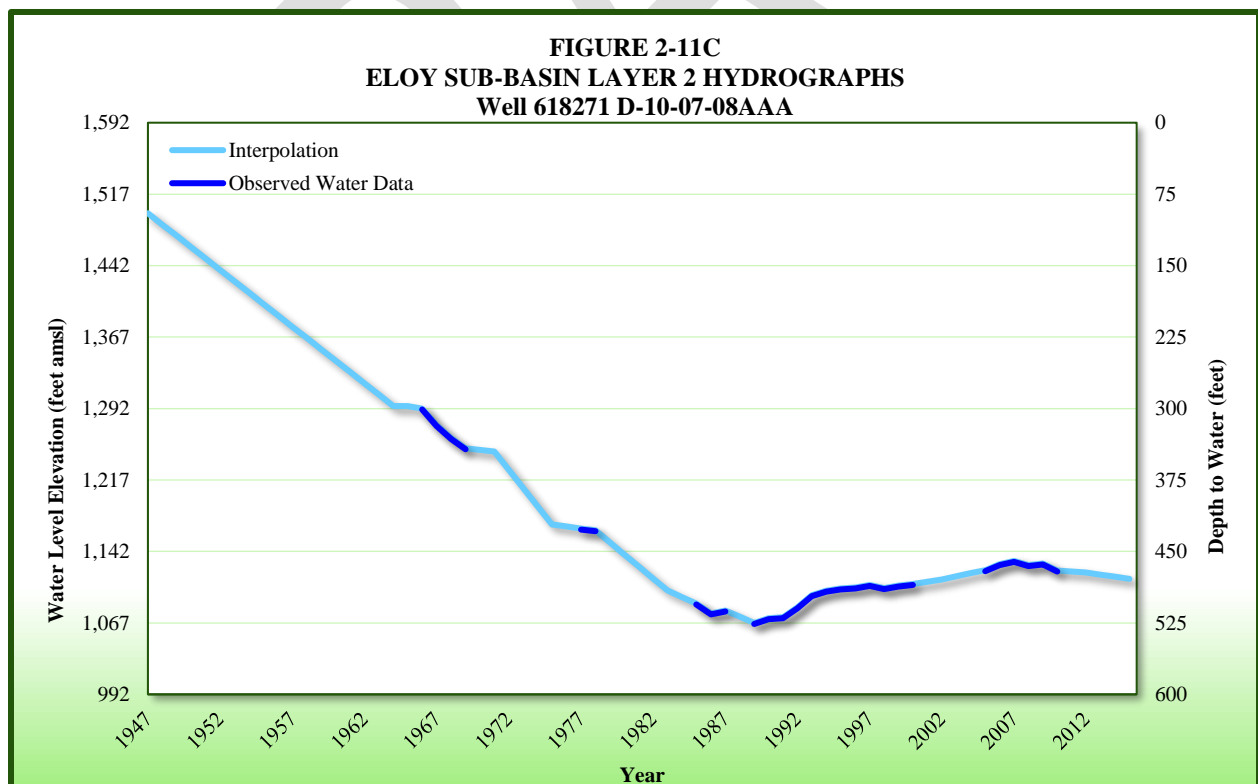
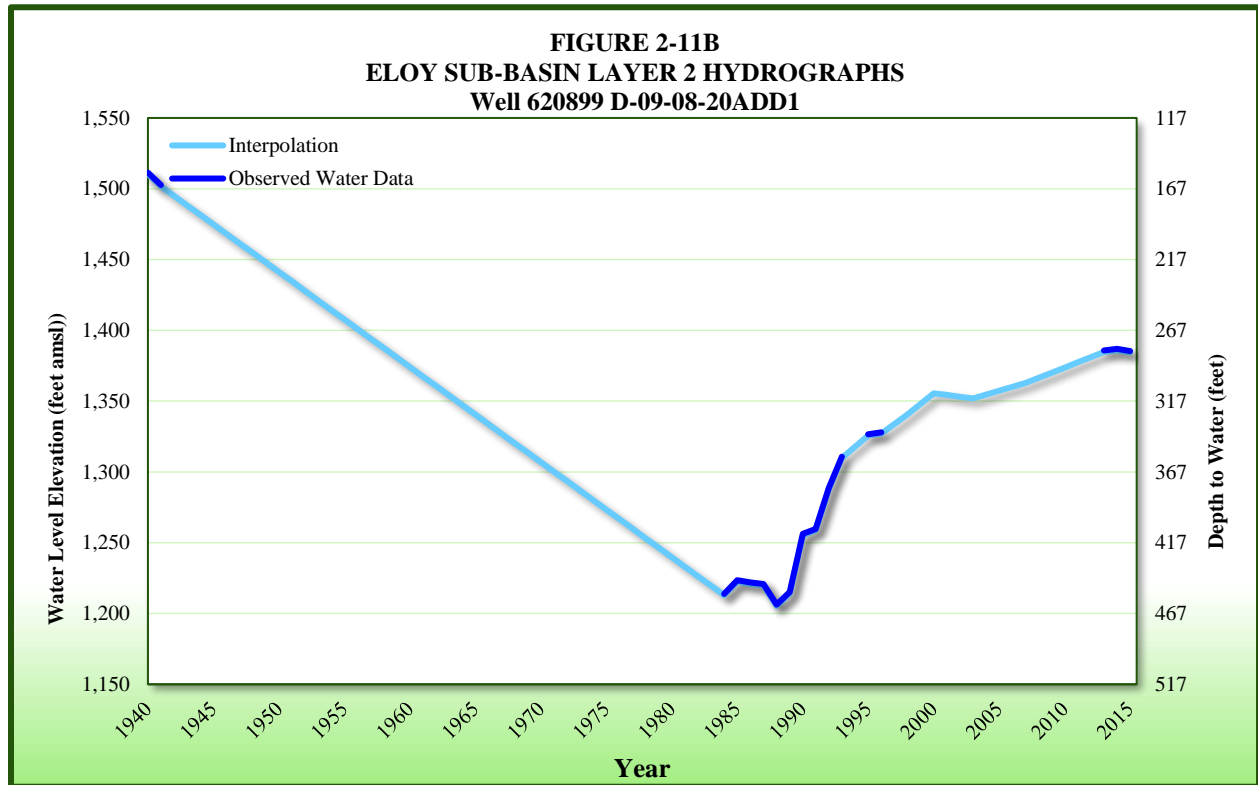


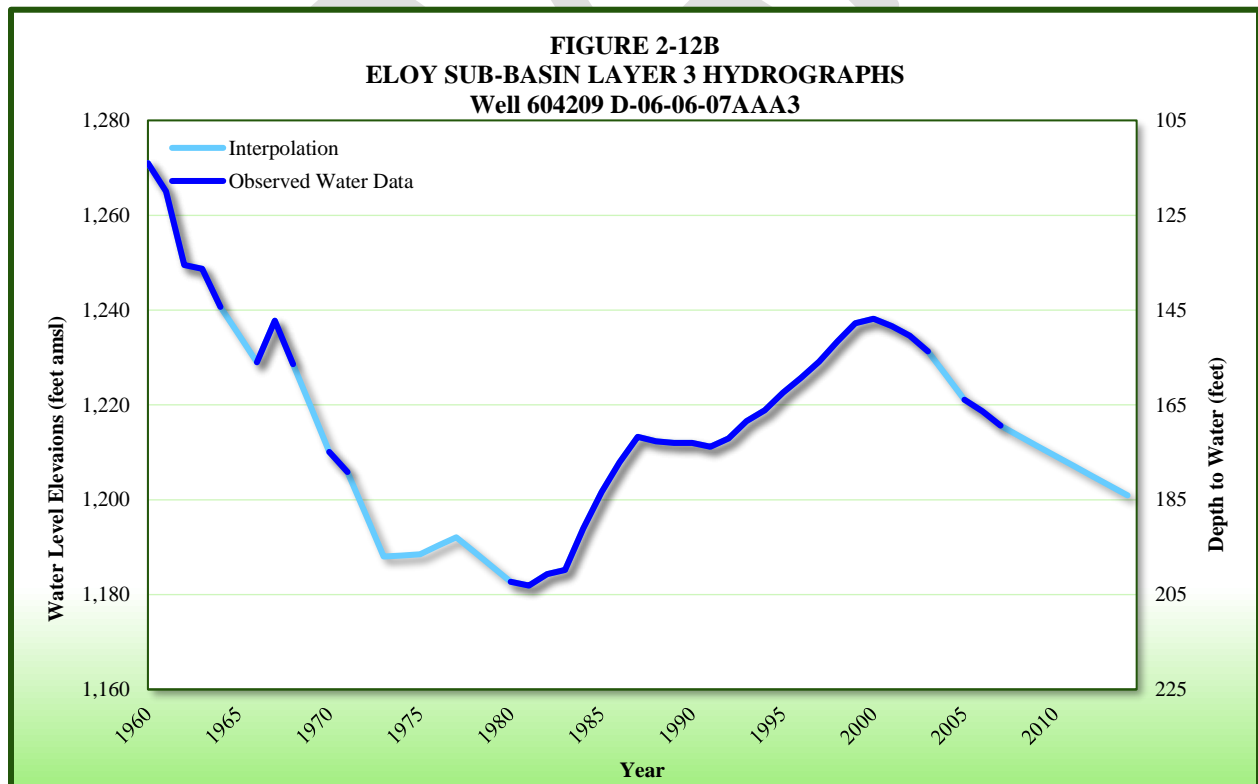
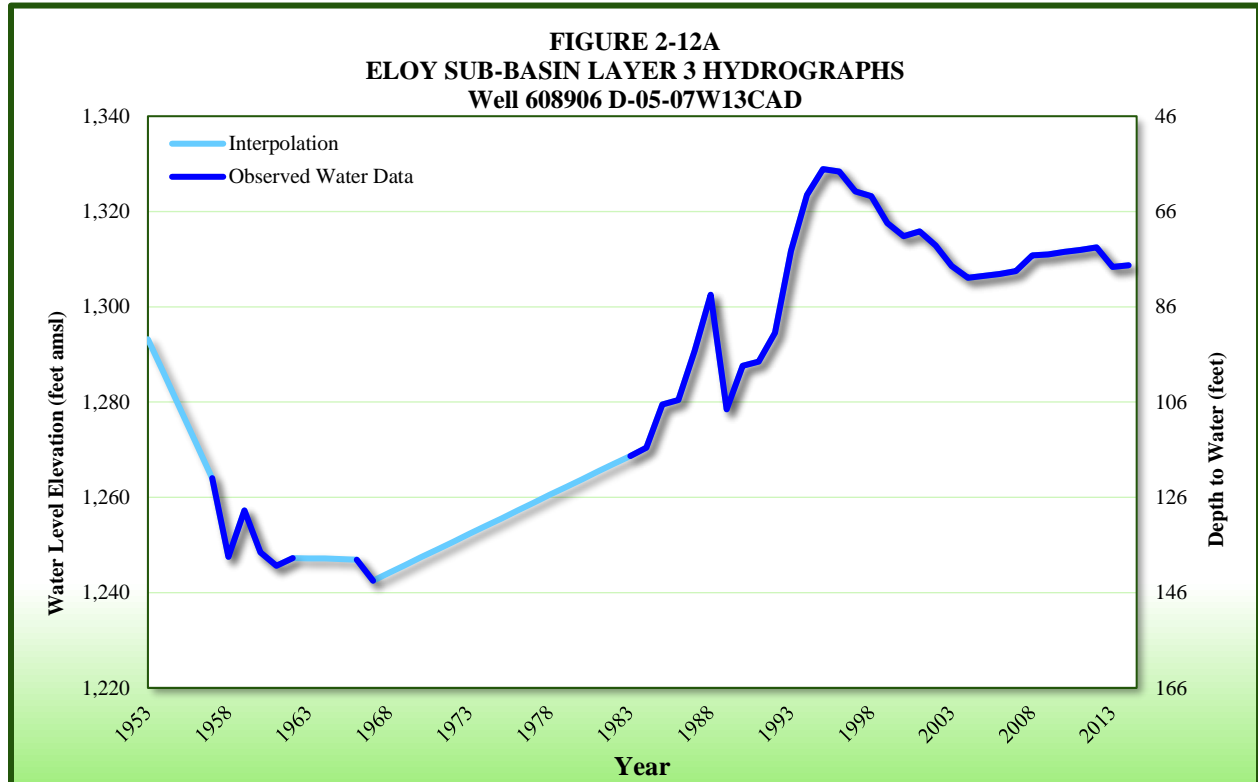
- | | |
|-----------------------|-----------|
| • City or Town | • Layer 1 |
| ◊ Pinal AMA | • Layer 2 |
| - - - Sub-basin | • Layer 3 |
| ~ Stream | |
| ▨ Hardrock | |
| □ County | |
| ⊞ ActiveModelBoundary | |

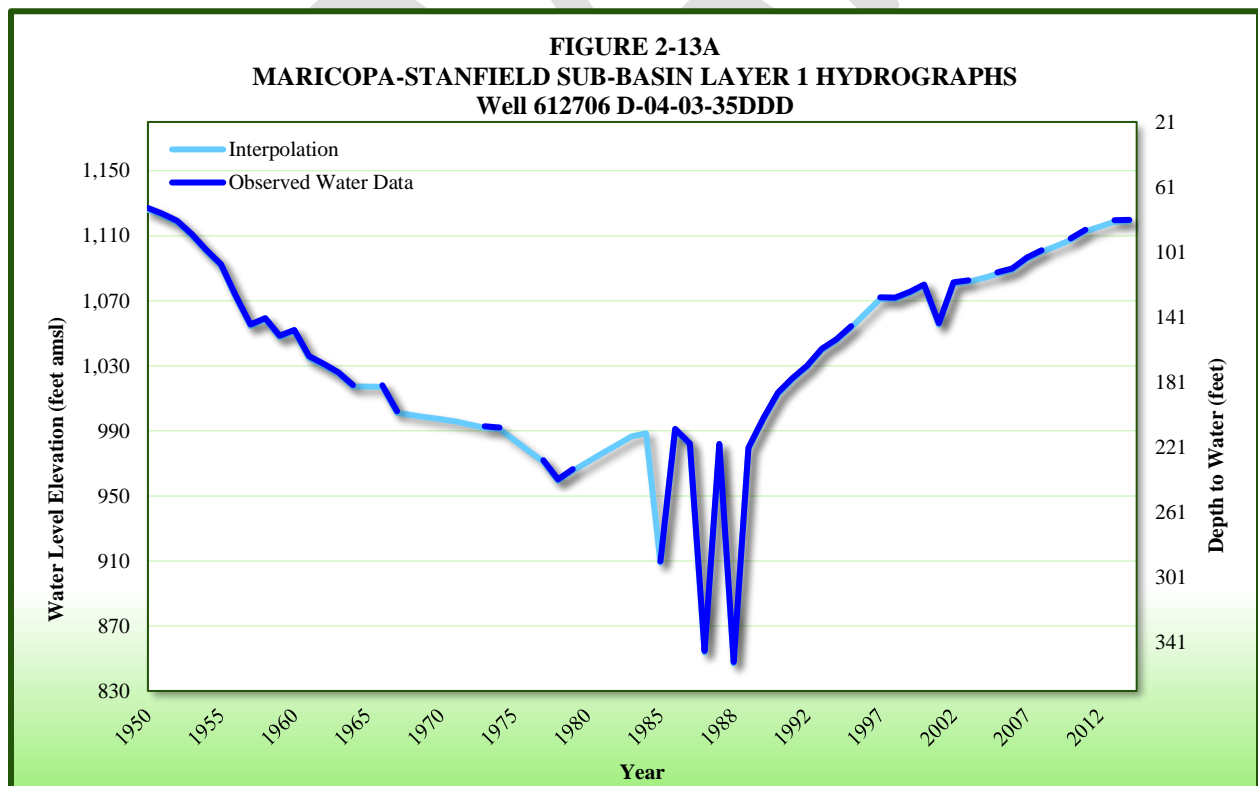
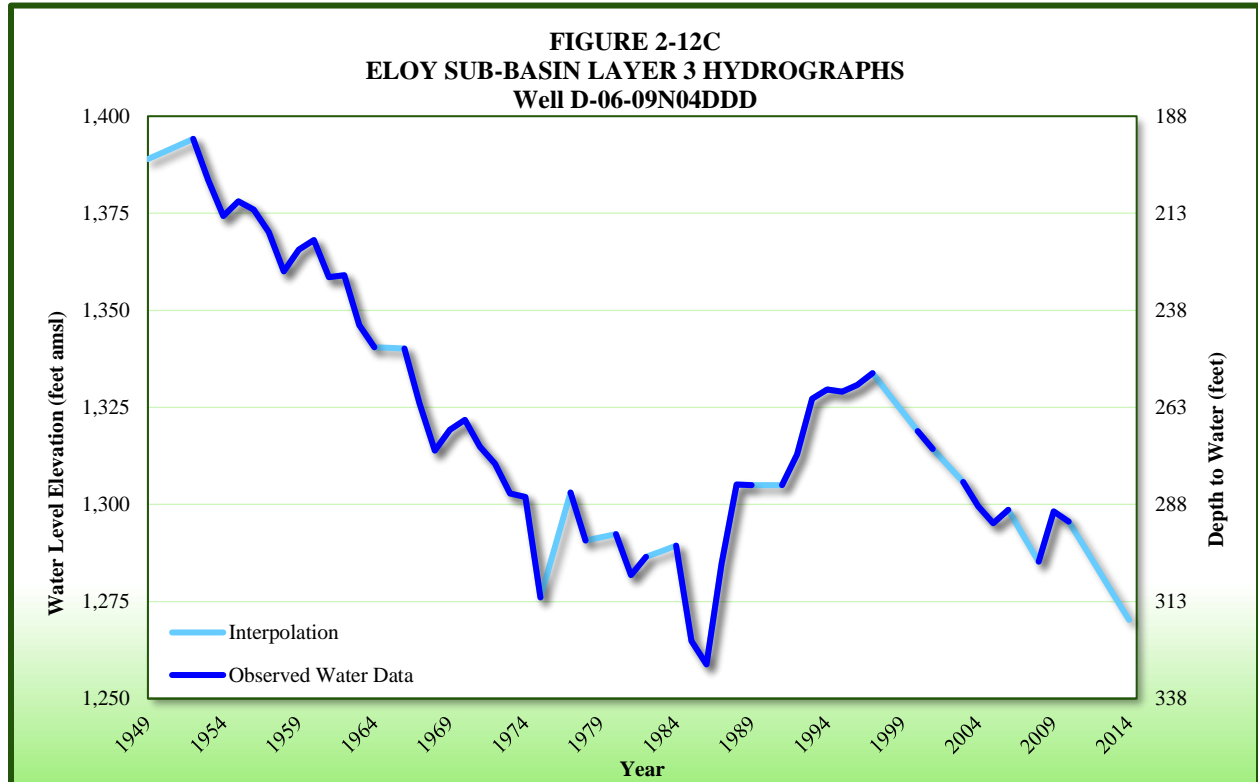


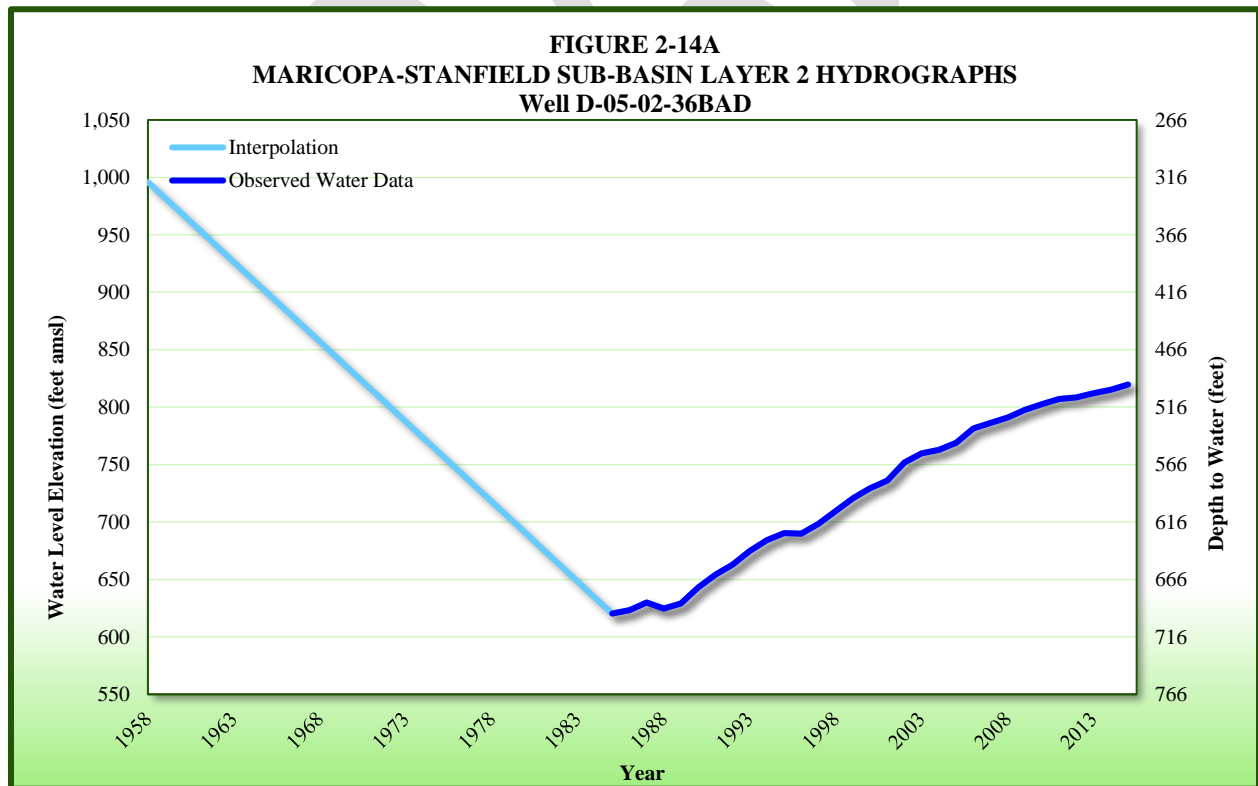
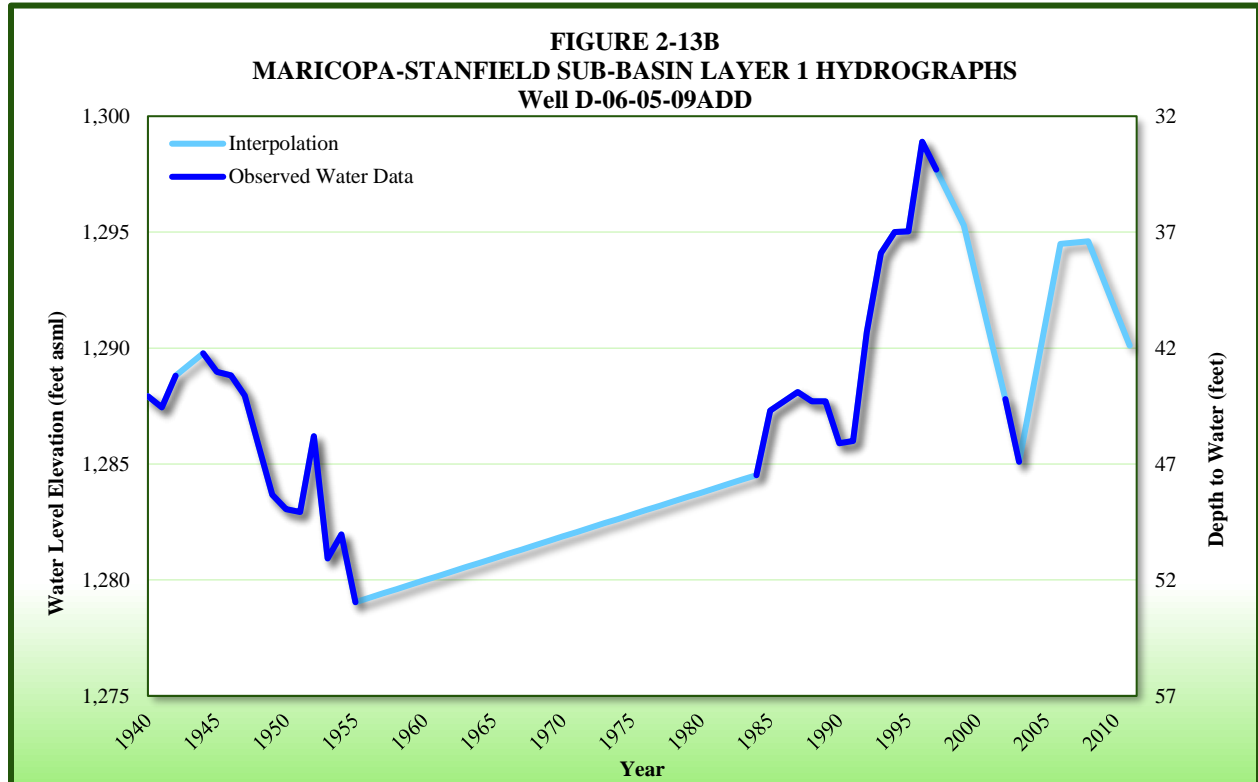


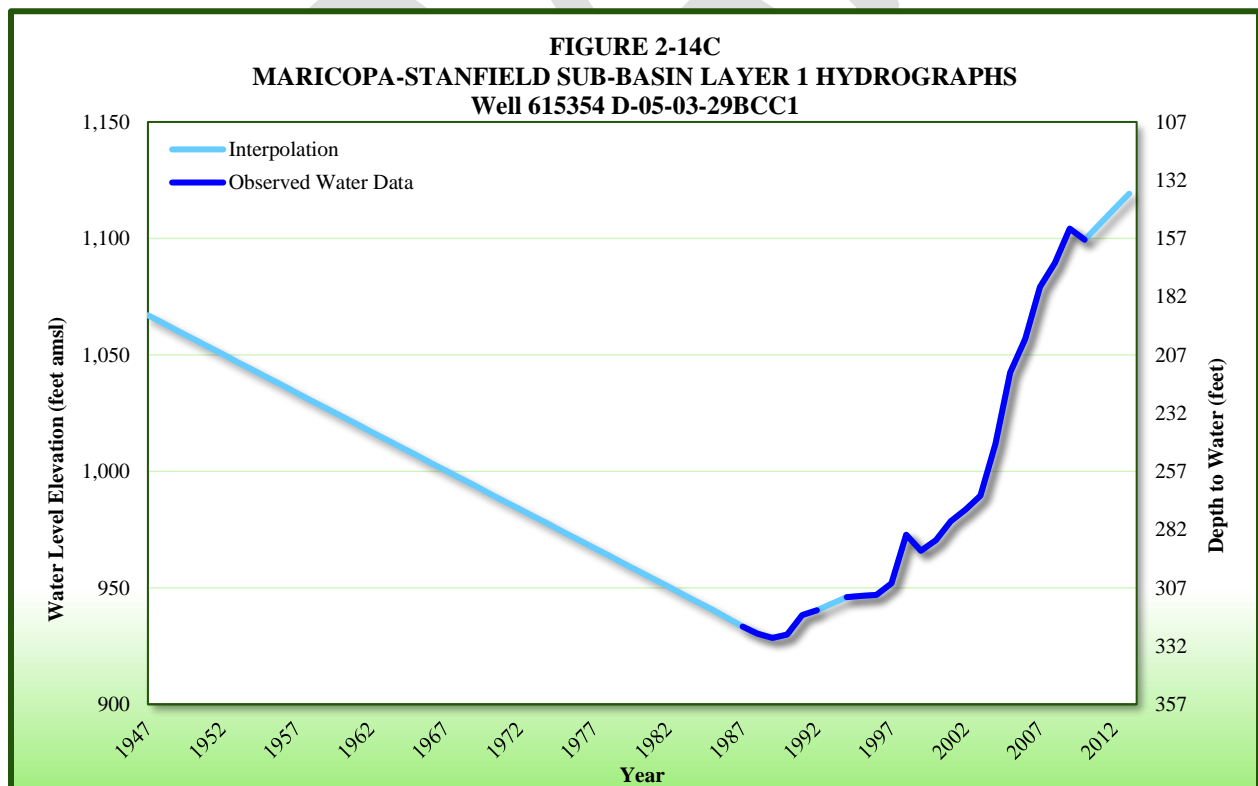
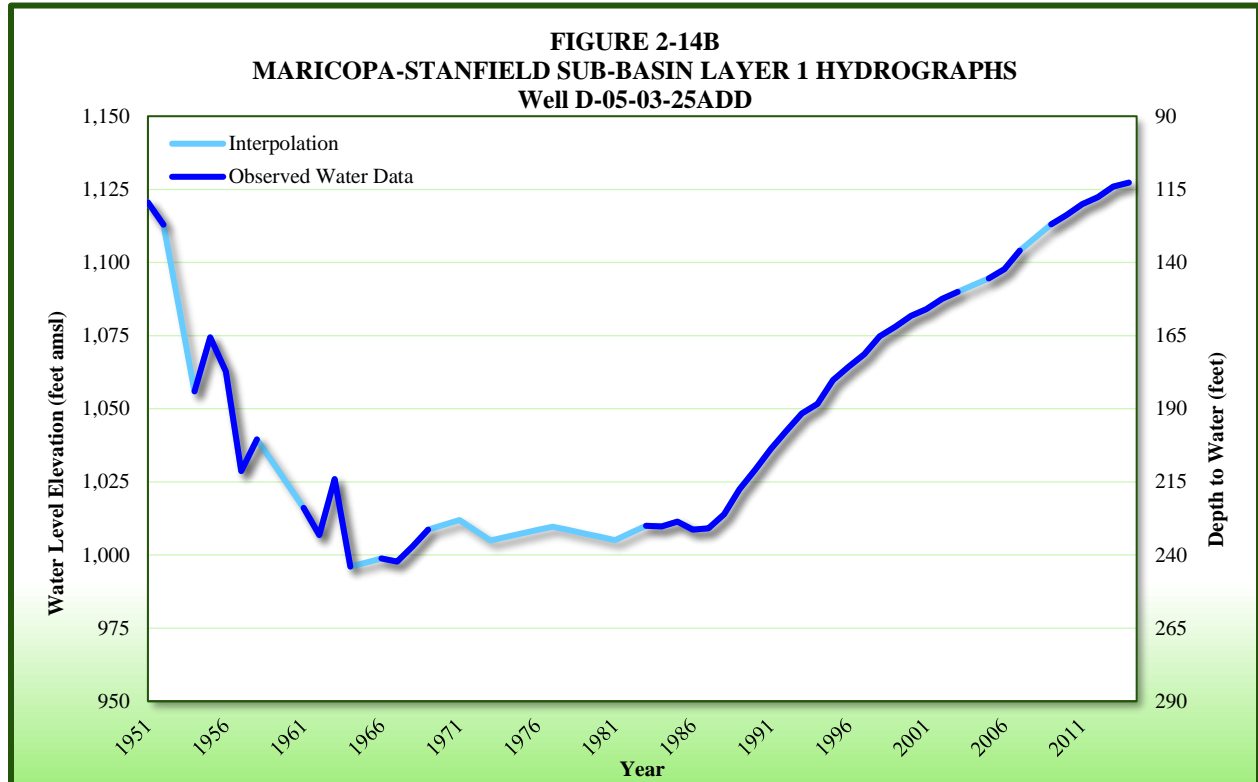


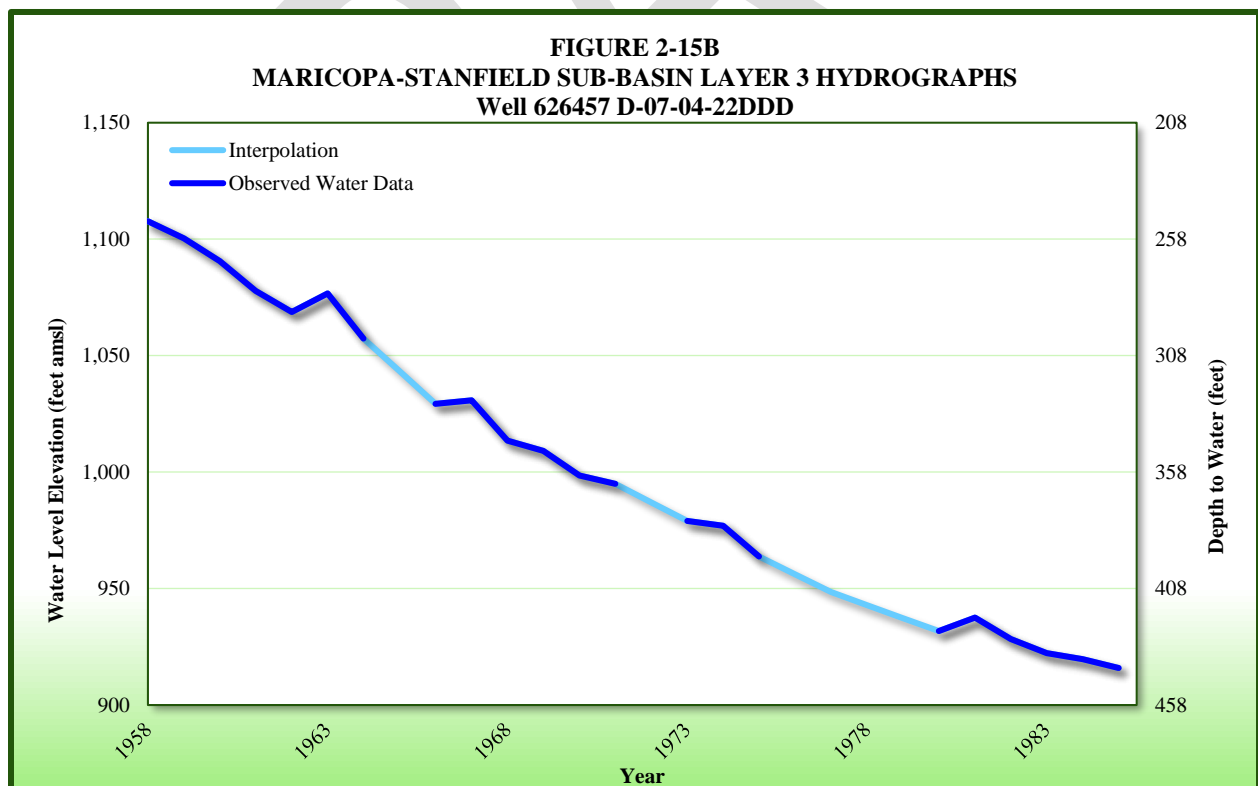
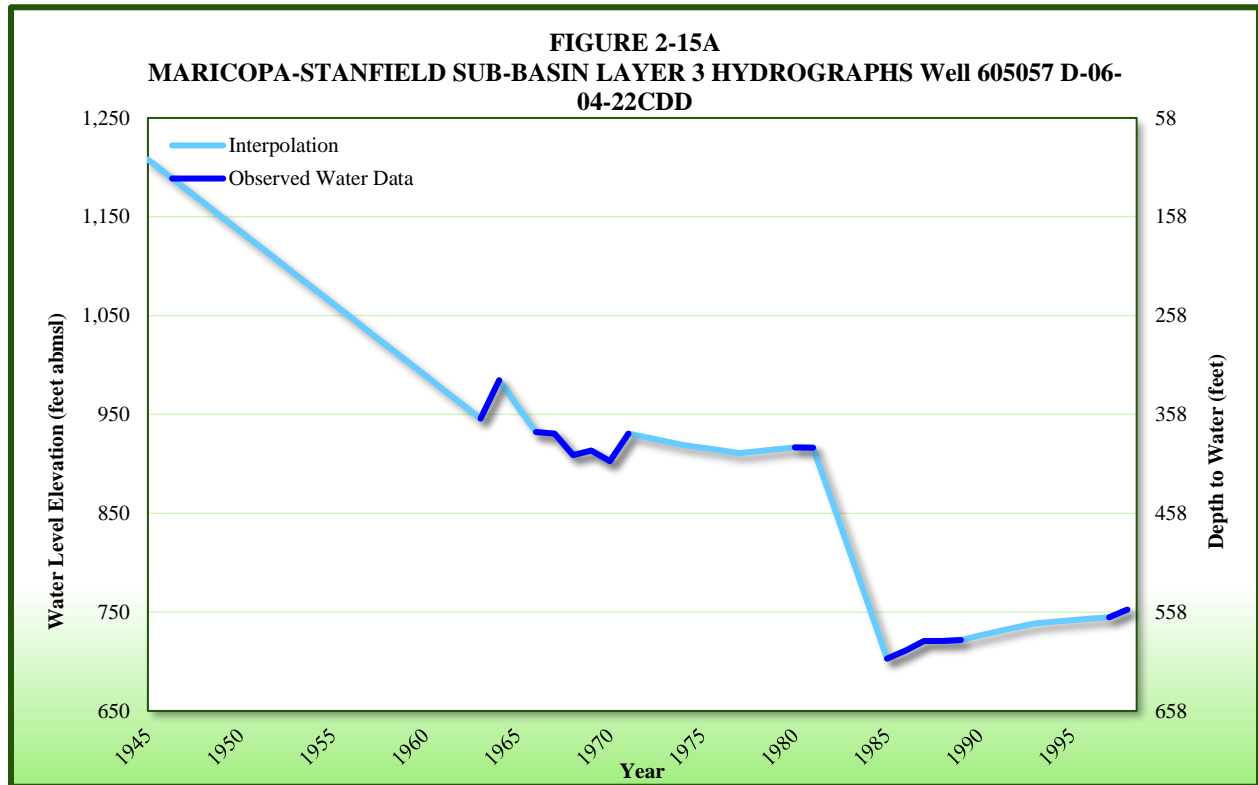












Water levels were measured at 388 locations in the Eloy Sub-Basin in both 2007 and 2013 with changes ranging between -123 feet to + 71 feet with an average of +0.3 feet increase. At 161 locations the water level dropped (became deeper) and at 227 the water level rose (became shallower) or remained the same. Water levels in wells screened in the UAU rose slightly more on average (+3.4 feet) than those screened in the MSCU (+1.2 feet). Water levels measured in wells screened in the LCU dropped 9.3 feet on average in that 6-year period. Other locations screened across multiple layers had both positive and negative water level changes.

Similar to the Maricopa-Stanfield Sub-basin, water level elevations have increased in the Eloy Sub-basin since the mid-1970s when they were at their lowest. Interpolated depths to water using all the measurements from both sweeps indicate an average increase of 1.78 feet/year between 1976 and 2013 in the upper layer. The increased water levels resulted from decreased pumping and increased use of CAP and surface water supplies in addition to the one-time release of water from interbed storage due to land subsidence and the arrival of lagged agricultural incidental recharge from earlier time periods. The Eloy Sub-basin also benefited from significant flood recharge from events in 1983 and 1993 along the Gila and Santa Cruz river channels. In locations in close proximity to these rivers temporary groundwater mounds were observed for a few years after the events that would dissipate during subsequent dry years. A perched water table is found in much of the Casa Grande area that ranges from less than 10 feet to about 100 feet below land surface.

2.6.4 2013 Water Level Elevation and Depth to Water Map

The 2013 measured water level elevation maps per layer for the Pinal Model Area are shown in Figures 2-16A – 2-16C. The water level elevation map shows the elevation of the water table above mean sea level. Due to the large vertical gradient in potentiometric head in the PAMA sub-basins, the water levels must be analyzed and illustrated as layer-specific surfaces. Also, no measurements were taken on the GRIC and so the contours do not extend into that area. The general direction of groundwater flow is from the southeast to the northwest. Water flows at right angles to the water level elevation contours, and from areas of high elevation to lower elevation. There are cones of depression in both layers 2 and 3, near heavy pumping areas. In those areas, water flows from every direction around the cone to the cone's center.

The depths-to-water per model layer in 2013 is shown in Figures 2-17A – 2-17C. The depth-to-water maps shows the depth of the water table below land surface. The contours are based on measured values from the 2013 sweep in areas where such data was available and in the GRIC area, they are based on the difference between the land surface and the PAMA groundwater flow model simulated heads at the end of the 2013 stress period. The direction of groundwater flow is not easily determined from a depth-to-water map. Depth-to-water maps are generally used for well location and design, and hydrologic interpretation.

FIGURE 2-16A
2013 WATER LEVEL ELEVATIONS UAU

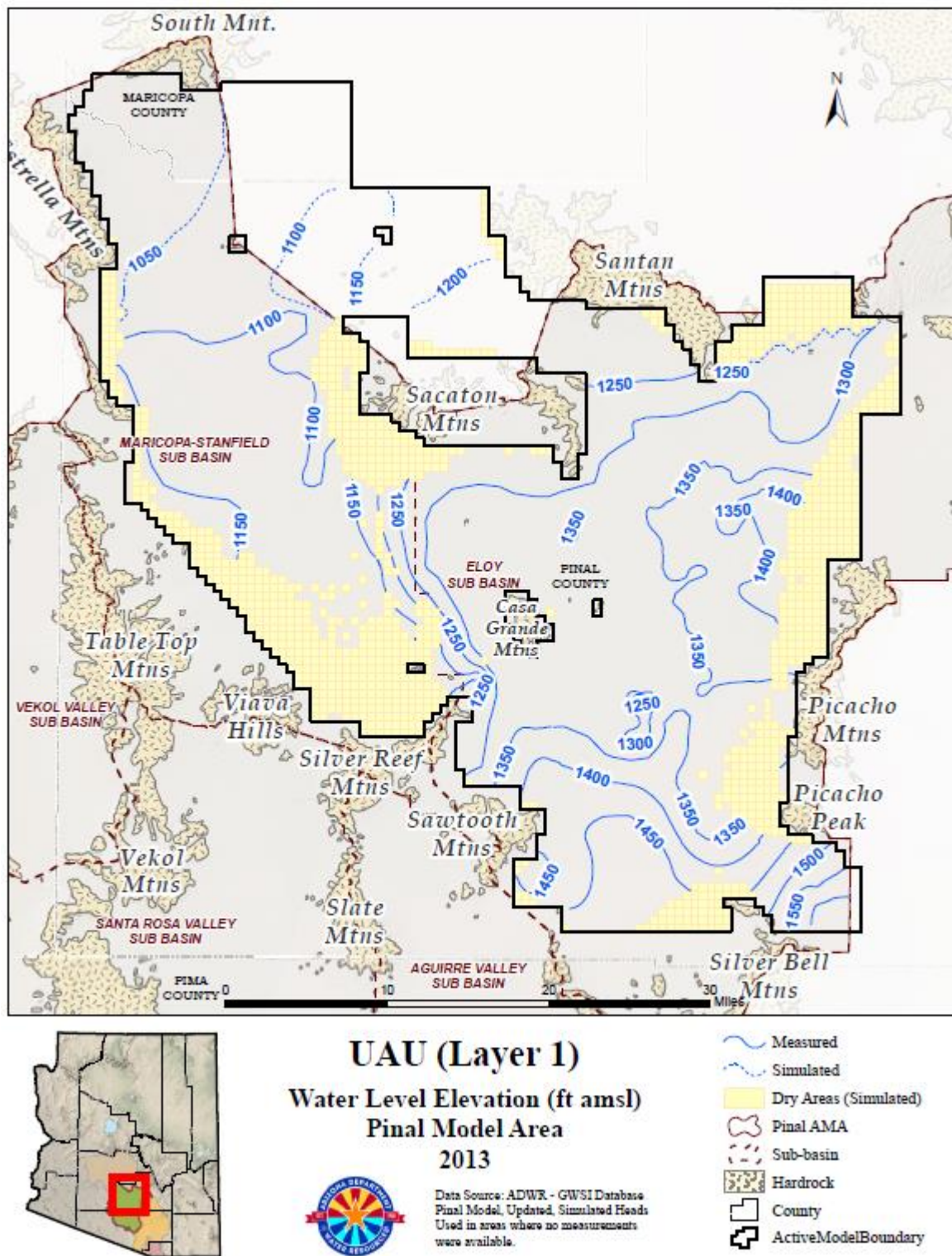
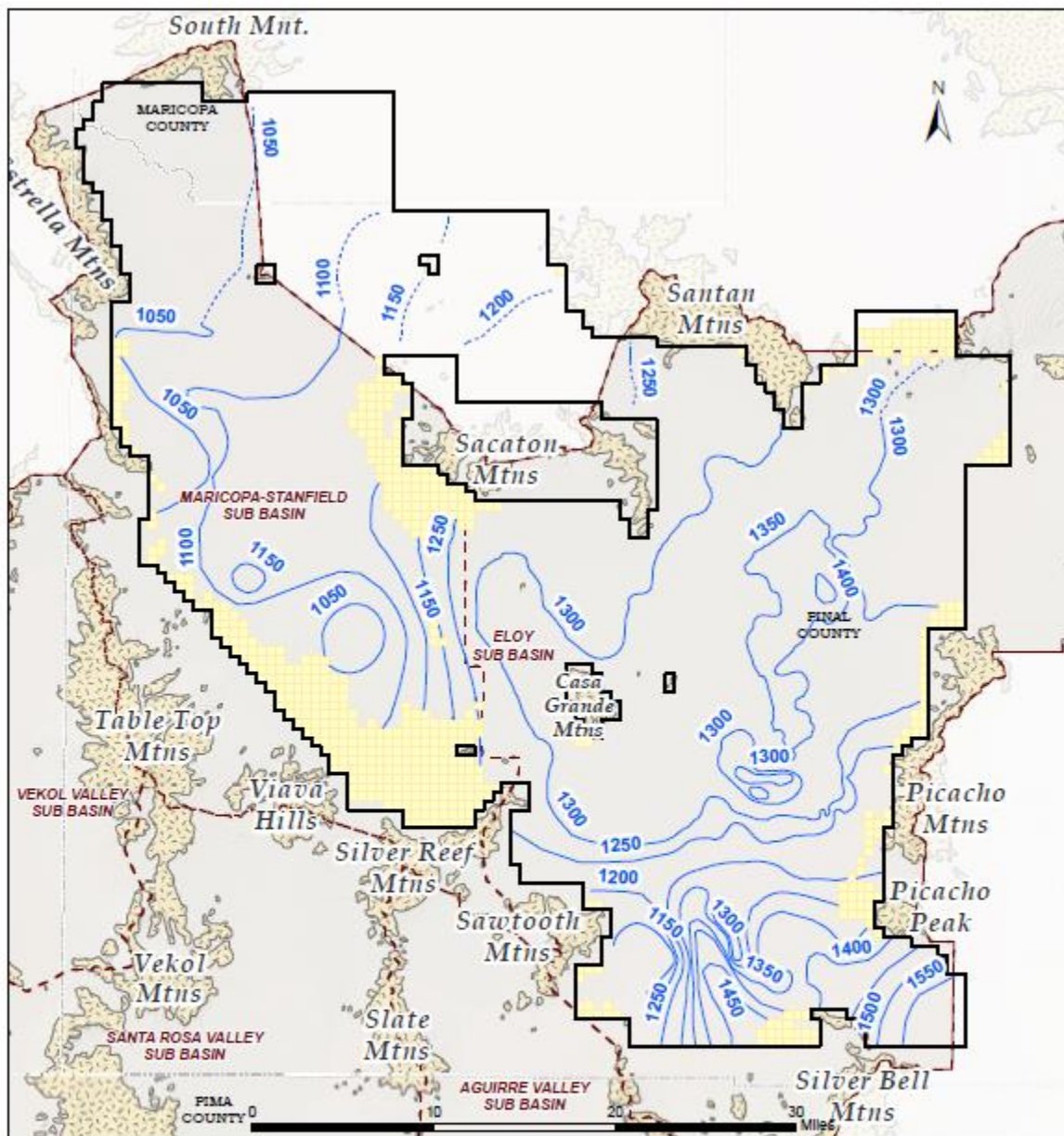


FIGURE 2-16B
2013 WATER LEVEL ELEVATIONS MCSU



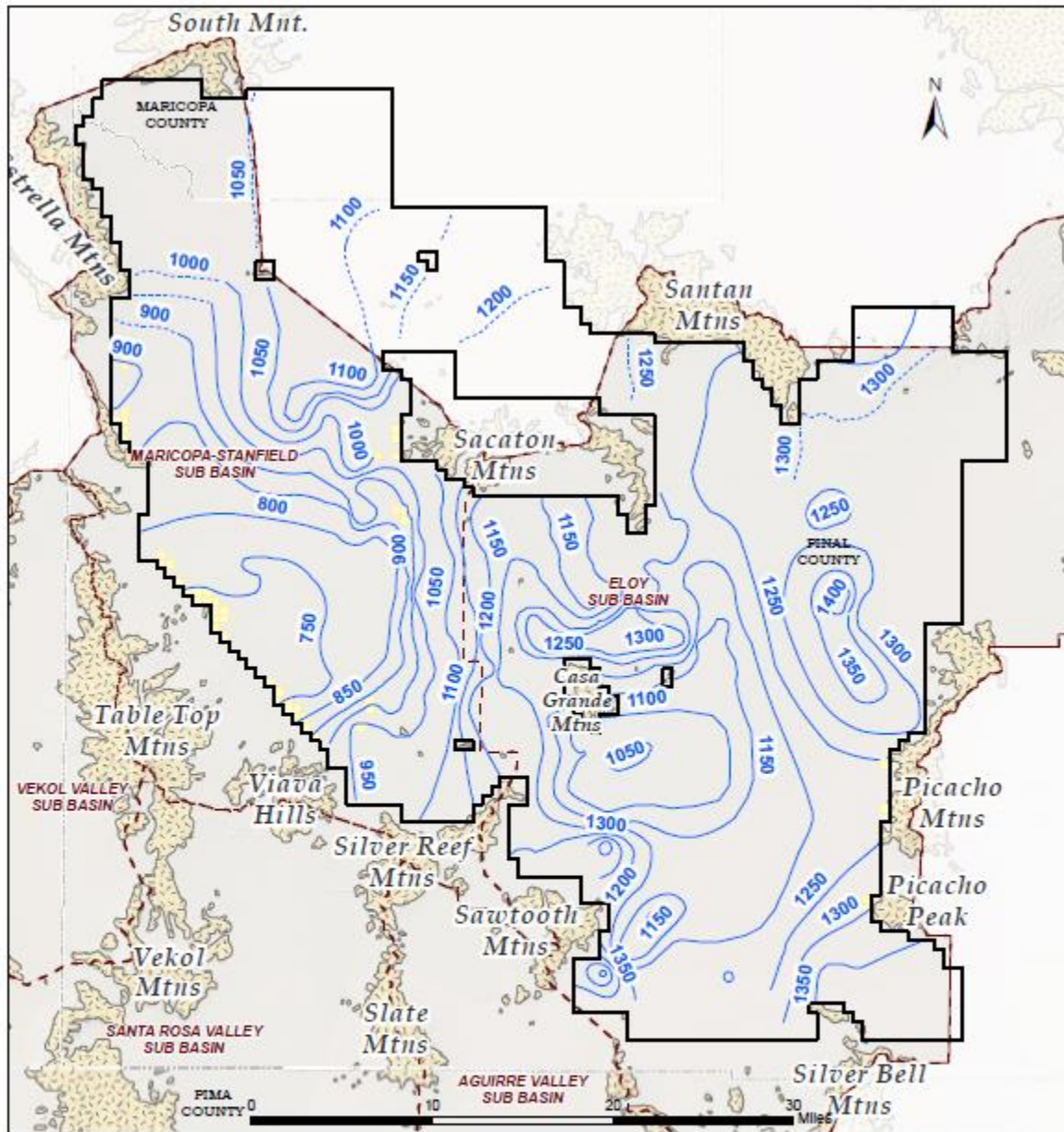
MCSU (Layer 2)
Water Level Elevation (ft amsl)
Pinal Model Area
2013



Data Source: ADWR - GWSI Database
 Pinal Model, Updated, Simulated Heads
 Used in areas where no measurements
 were available.

- Measured
- Simulated
- Dry Areas (Simulated)
- Pinal AMA
- Sub-basin
- Hardrock
- County
- ActiveModelBoundary

FIGURE 2-16C
2013 WATER LEVEL ELEVATIONS LCU



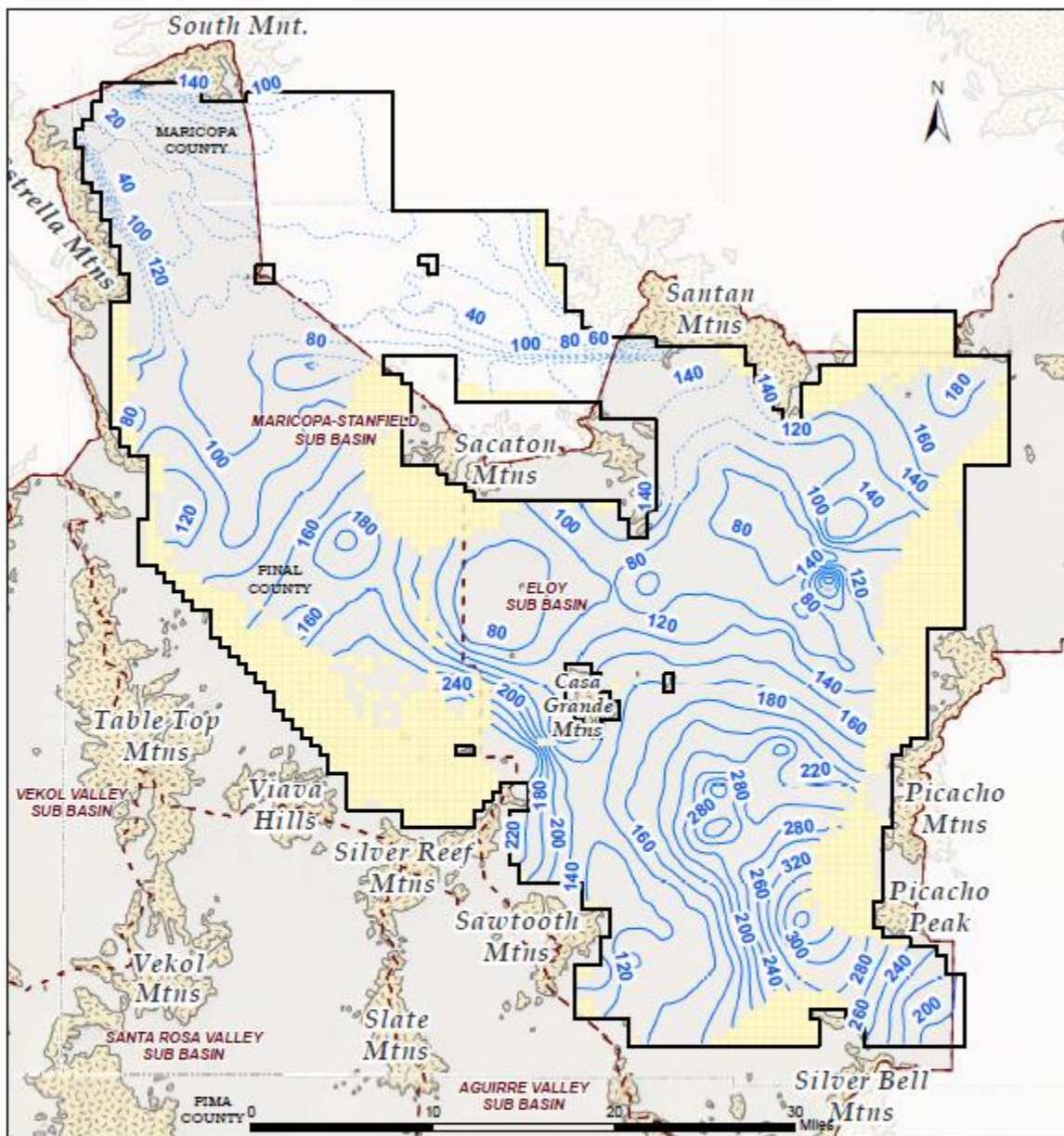
LCU (Layer 3)
Water Level Elevation (ft amsl)
Pinal Model Area
2013



Data Source: ADWR - GWSI Database
 Pinal Model, Updated, Simulated Heads
 Used in areas where no measurements
 were available.

- Measured
- Simulated
- Dry Areas (Simulated)
- Pinal AMA
- Sub-basin
- Hardrock
- County
- Active Model Boundary

FIGURE 2-17A
2013 DEPTHS TO WATER UAU



UAU (Layer 1)

Depth to Water (feet)
 Pinal Model Area
 2013



Data Source: ADWR - GWSI Database
 Pinal Model, Updated, Simulated Heads
 Used in areas where no measurements
 were available.

- Measured
- - - Simulated
- Dry Areas (Simulated)
- Pinal AMA
- - - Sub-basin
- Hardrock
- County
- ActiveModelBoundary

FIGURE 2-17B
2013 DEPTHS TO WATER MCSU

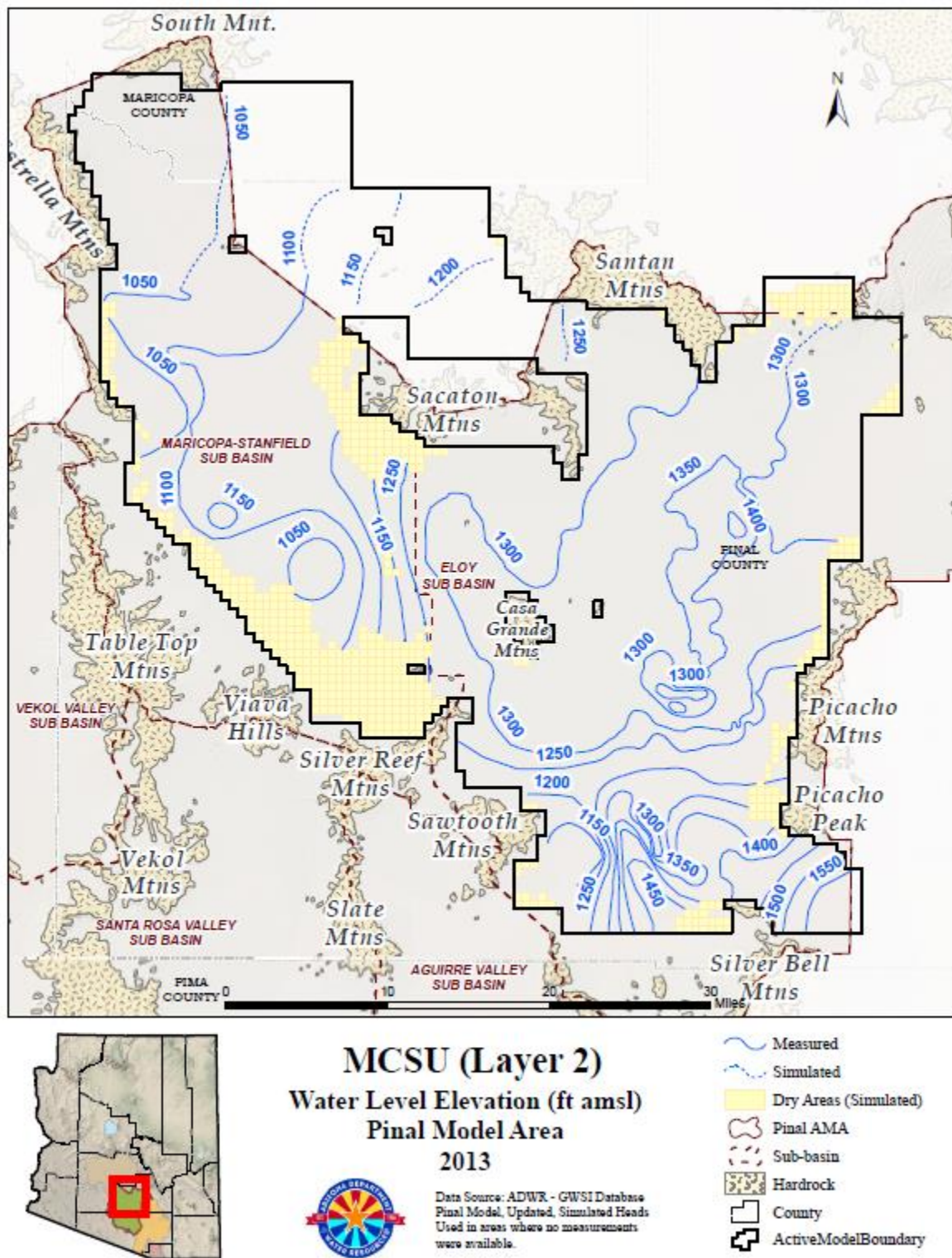
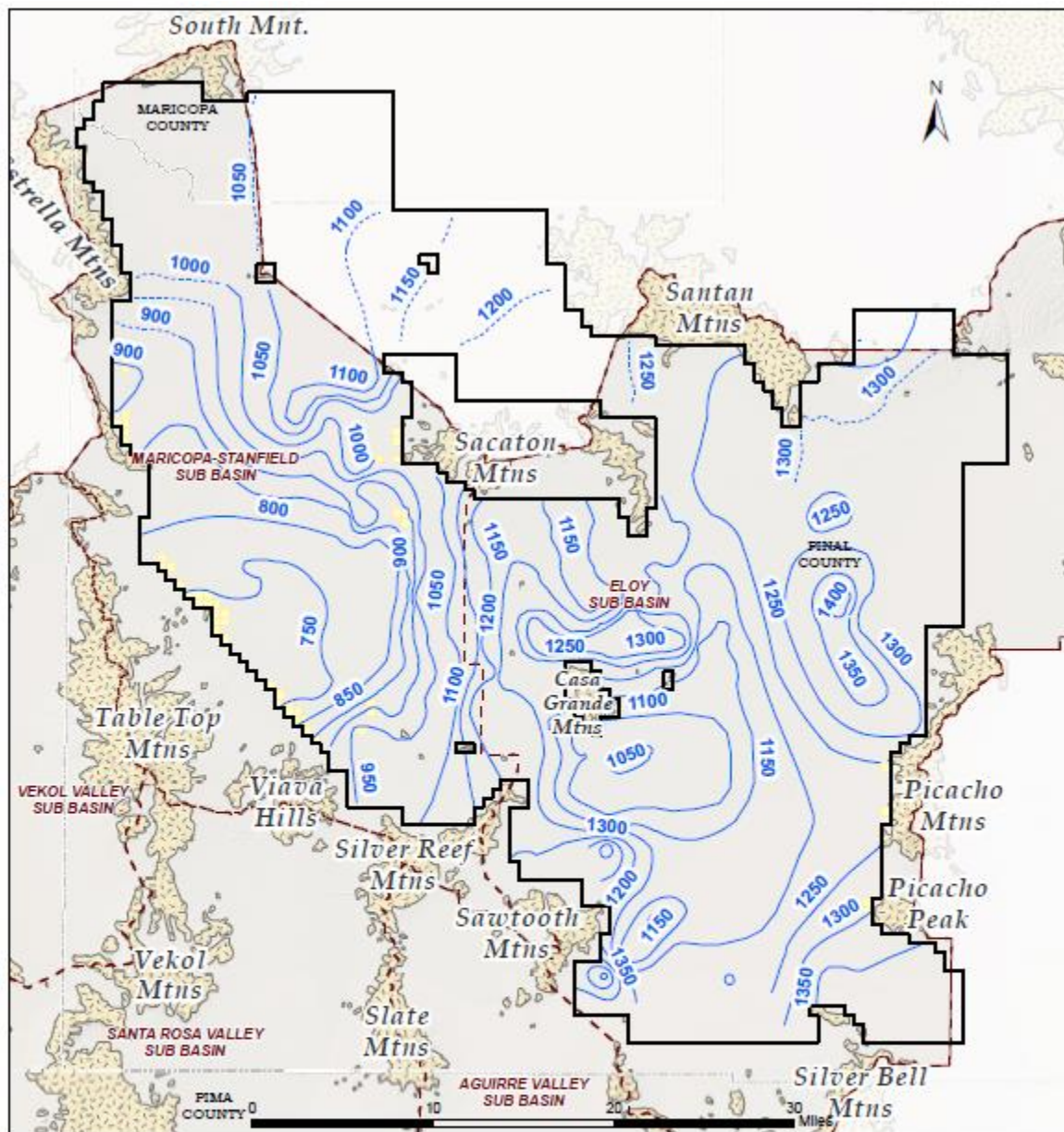


FIGURE 2-17C
2013 DEPTHS TO WATER LCU



LCU (Layer 3)
Water Level Elevation (ft amsl)
Pinal Model Area
2013



Data Source: ADWR - GWSI Database
 Pinal Model, Updated, Simulated Heads
 Used in areas where no measurements
 were available.

- Measured
- - - Simulated
- Dry Areas (Simulated)
- Pinal AMA
- - - Sub-basin
- Hardrock
- County
- ActiveModelBoundary

2.6.4.1 Estimated Groundwater-in-storage and Change-in-storage

Information on aquifer thickness, depth-to-water, and aquifer storage properties can be used to estimate the volume of water in storage in an aquifer. The estimated groundwater-in-storage to 1,100 feet below land surface for the area covered by the PAMA groundwater flow model in 2013 is 40.36 million ac-ft (*See Table 2-4*). The Maricopa-Stanfield Sub-basin groundwater-in-storage is estimated to be 16.47 million ac-ft, and the groundwater-in-storage for the Eloy Sub-basin is estimated to be 23.90 million ac-ft (Corkhill, 2015).

TABLE 2-4
PINAL AMA MODEL GROUNDWATER IN STORAGE ESTIMATE

Sub-basin	Indian (ac-ft)	Non-Indian (ac-ft)	TOTAL (ac-ft)
Maricopa-Stanfield	9,088,523	7,379,330	16,467,853
Eloy	1,414,228	22,487,458	23,901,686
TOTAL	10,502,751	29,866,788	40,369,539

2.7 LAND SUBSIDENCE

In areas of intensive groundwater development and subsequent groundwater declines, the land surface may subside, which may result in economic consequences. Land subsidence may cause earth fissures which can result in damage to farmland, irrigation canals, sewage systems, well casings, floodplains, and structural foundations. Erosion along earth fissures may reverse drainage patterns and render land unsuitable for irrigation. Inelastic compaction and reduced pore space of alluvial sediments following land subsidence decreases the water storage potential of aquifers. In the PAMA, land subsidence and earth fissuring have been recognized as problems for many years. In some areas, land subsidence has been substantial.

Land subsidence and earth fissuring are a direct result of groundwater depletion and water level declines, which, in turn, induce compaction of fine-grained sediments in the deep groundwater basins. Benchmark leveling data has indicated land subsidence has occurred throughout the Maricopa-Stanfield and Eloy sub-basins. By 1967, land subsidence was measured at 11.8 feet near the community of Stanfield, and 12.5 feet near the City of Eloy (Laney, Raymon, & Winikka, 1978). An additional 2.4 feet of land subsidence was measured near the community of Stanfield and 4.8 feet near Picacho during leveling observations by the National Geodetic Survey (NGS) between 1967 and 1980 (*Figure 2-18*). A final leveling run by the NGS in 1992 near the Picacho area measured an additional 1.8 feet of land subsidence since 1980. Taking into account the historical leveling results and recent ADWR data, land subsidence in the Picacho area is approaching 20 feet.

Earth fissures were first reported in 1927, near the eastern edge of the Eloy Sub-basin adjacent to the Picacho Mountains (Carpenter, 1988). Today the earth fissure zone near the Picacho Mountains extends along a north-south line for approximately nine miles. The Arizona Geological Survey (AZGS) is the state agency responsible for monitoring and mapping earth fissures around the state. As of 2012, the AZGS has mapped more than 124 miles of earth fissures in the PAMA (*Figure 2-19*).

Recent ADWR land subsidence monitoring and land subsidence maps published annually on ADWR's website provide further evidence of land subsidence in the PAMA, particularly the Maricopa-Stanfield and the Picacho-Eloy areas.

ADWR has been monitoring land subsidence in the PAMA using a satellite-based remote-sensing system since 2005, collecting, processing, and analyzing Interferometric Synthetic Aperture Radar (InSAR) data. Two separate land subsidence features have been detected in the PAMA using InSAR data. The first feature, referred to as the Maricopa-Stanfield feature, is located between the City of Maricopa, the community of Stanfield, and the City of Casa Grande. The second feature, referred to as the Picacho-Eloy feature is located between the Picacho Mountains and Coolidge.

ADWR has processed archived and regularly scheduled InSAR data from January 2004 to September 2010 (*Figures 2-20 and 21*), May 2010 to April 2015 (*Figure 2-22*), and May 2010 to April 2014 (*Figure 2-23*) for the PAMA. Total compaction and land subsidence rates for the two land subsidence features are listed in Table 2-5.

TABLE 2-5
PINAL AMA LAND SUBSIDENCE BASED ON ADWR INSAR DATA

	Picacho-Eloy Subsidence (ft)	Rate (ft/yr)	Maricopa-Stanfield Subsidence (ft)	Rate (ft/yr)
01/2004 - 09/2010	0.26	0.04	0.26	0.04
05/2010 - 03/2014	0.39	0.1	0.3	0.08
Total Subsidence	0.65	0.06	0.56	0.05

Groundwater levels have been rapidly rising in many areas within the PAMA since the early to mid-1990s (*See Hydrograph Figures 2-10 through 2-15*). The rises in groundwater levels, mainly caused by reduced groundwater pumping and the introduction of CAP surface water, is the main cause for the decrease in land subsidence rates compared to higher rates in the 1950s – 1980s in the PAMA. A number of wells used to monitor groundwater levels (*See Table 2-6*) are measured annually, providing ADWR with accurate groundwater level change data (*See Figure 2-24*) that is analyzed with current and historical land subsidence data.

TABLE 2-6
PINAL AMA MONITORING WELLS NEAR LAND SUBSIDENCE FEATURES (feet)

Groundwater Monitoring Well	12/2003 - 12/2007 Water level Change	10/2002 – 12/2009 Water level Change	12/2003 – 11/2011 Water level Change
D-05-09 03DAB	-5.7		
D-06-08 04ADD1	-2.6		
D-07-08 30CDD	5.1		
D-08-08 10CDD			-15.9
D-10-07 08AAA		16.6	
D-04-03 20DCD			24.1
D-05-03 25ADD			30
D-07-05 07DDD			-1.7

NOTE: A positive value represents rising water levels and a negative value represents dropping water levels.)

As the groundwater level and InSAR data indicates, aquifer compaction may continue to occur with the recovery of groundwater levels. This phenomenon is known as residual land subsidence. Residual

compaction and land subsidence will continue to occur even as groundwater levels rise, as long as water continues to slowly drain from the fine grain compressible sediments. Land subsidence will only cease once the groundwater system reaches equilibrium, that is, the heads in the fine grained sediments equilibrate with the heads in the surrounding aquifers. Even though groundwater levels may recover to previously high levels after land subsidence occurs, because the aquifer material has been compacted, the pore space available for groundwater storage is reduced so less groundwater is available for pumping. Also, once land subsidence has occurred, the addition of water to the subsurface cannot return land to its original elevation (Slaff, 1993). In addition to potential impacts on the structural integrity of buildings, pumping wells, pipelines, water conveyance infrastructure, improved highways, railroads, and roads, land subsidence is suspected of causing significant changes in floodplain runoff patterns, particularly along the Santa Cruz River in the PAMA.

Continued lowering of groundwater levels could potentially result in additional land subsidence. Because there is potential for significant damage due to land subsidence in the PAMA, mitigation of groundwater overdraft in land subsidence-prone areas continues to be one of ADWR's primary groundwater management objectives for the PAMA. ADWR will continue to monitor land in the PAMA using regularly scheduled InSAR data collection and analysis.

FIGURE 2-18
NATIONAL GEODETIC SURVEY LEVEL LINE SURVEY RESULTS
IN THE PINAL AMA

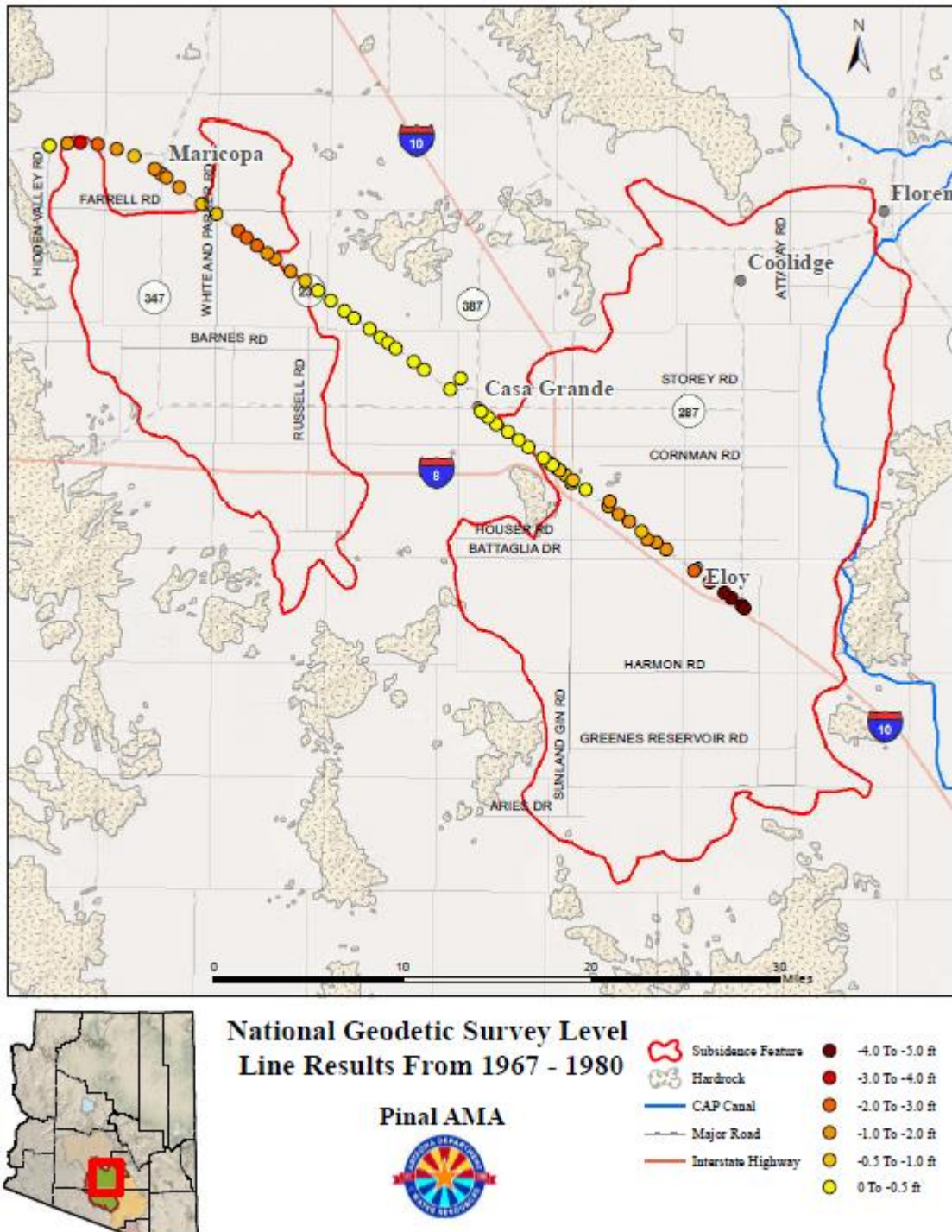


FIGURE 2-19
MAPPED EARTH FISSURES IN THE PINAL AMA

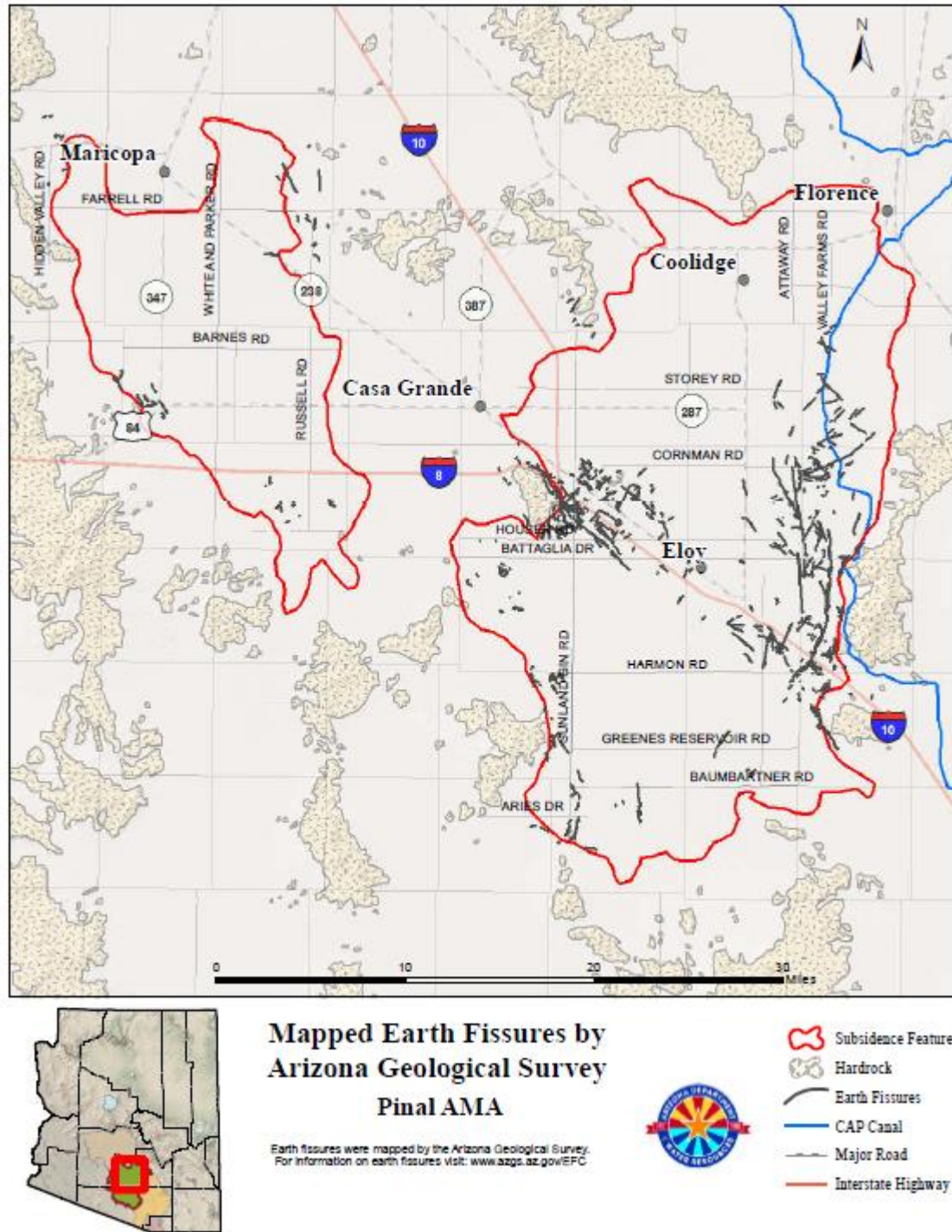


FIGURE 2-20
LAND SUBSIDENCE IN THE PICACHO-ELOY AREA 01/2004 - 09/2010

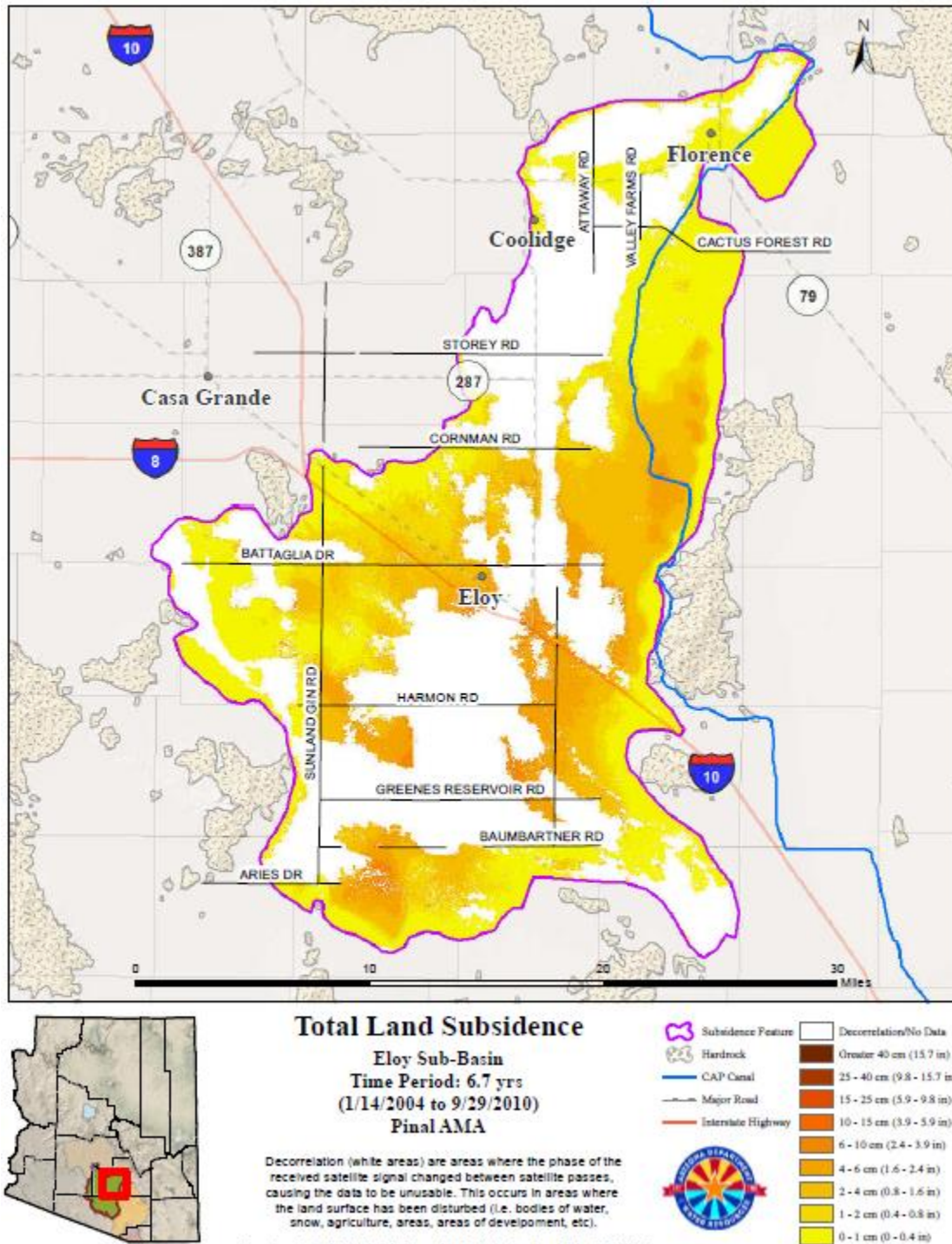


FIGURE 2-21
LAND SUBSIDENCE IN THE MARICOPA-STANFIELD AREA 01/2004 - 09/2010

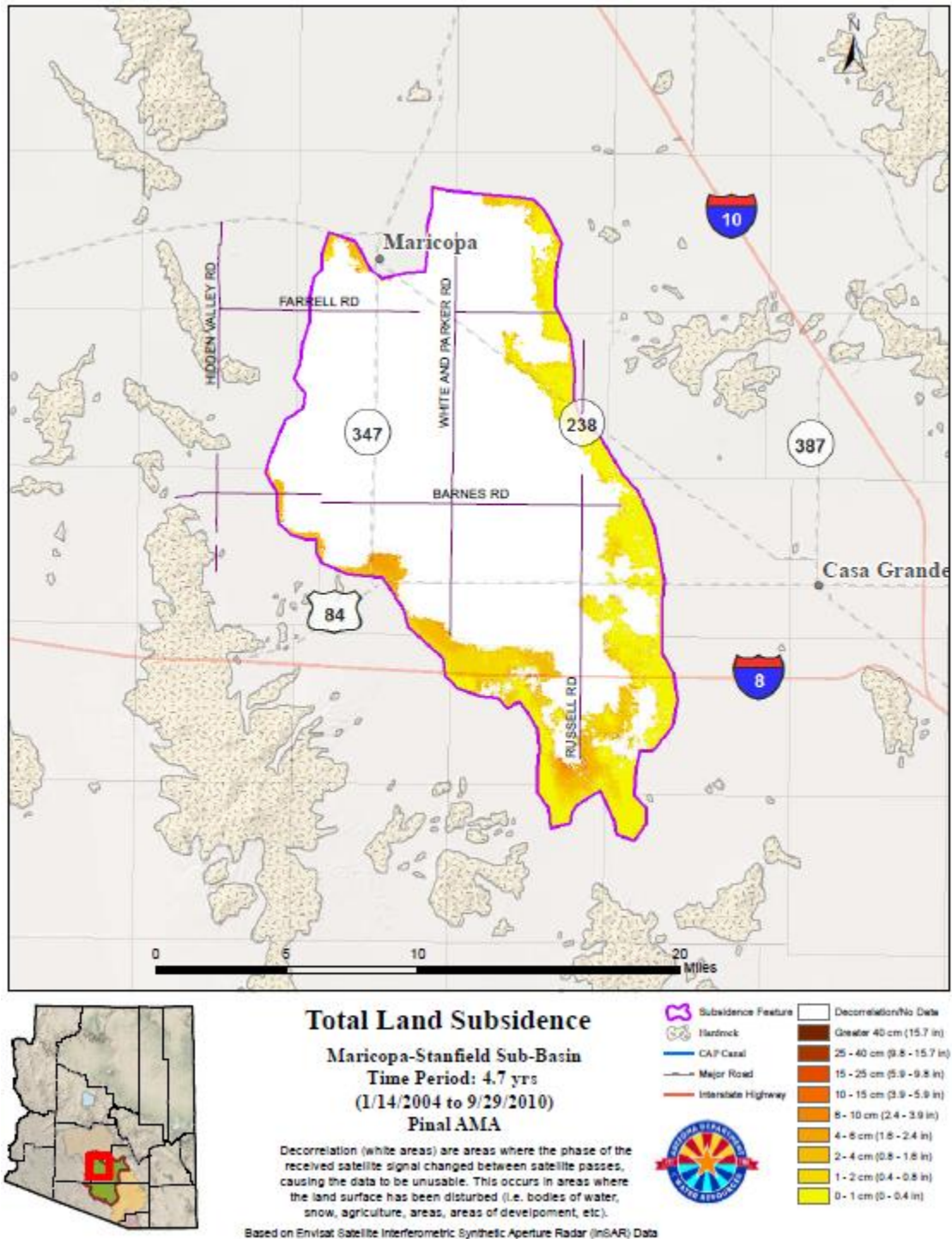


FIGURE 2-22
LAND SUBSIDENCE IN THE PICACHO-ELOY AREA 05/2010 - 04/2015

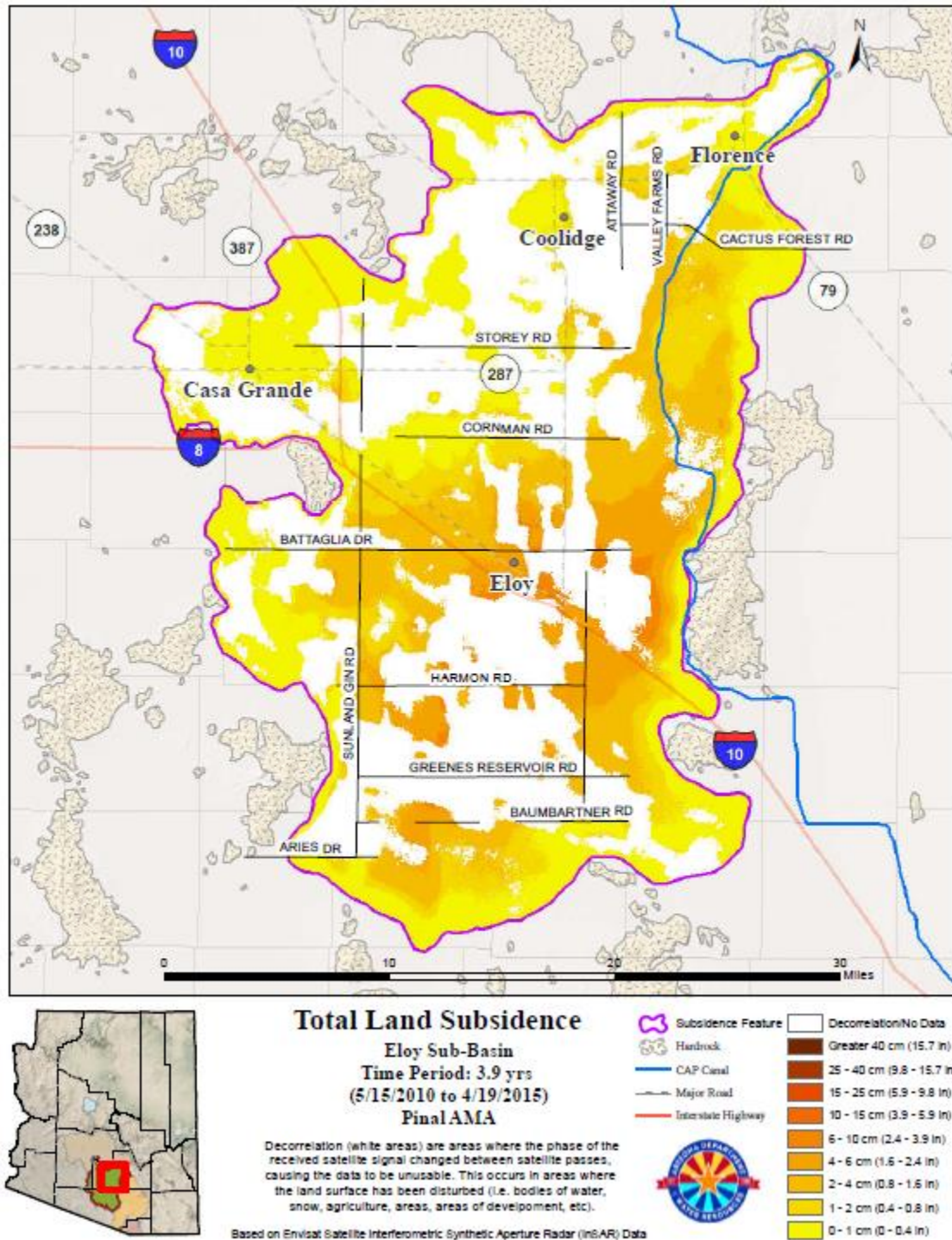


FIGURE 2-23
LAND SUBSIDENCE IN THE MARICOPA-STANFIELD AREA 05/2010 - 04/2014

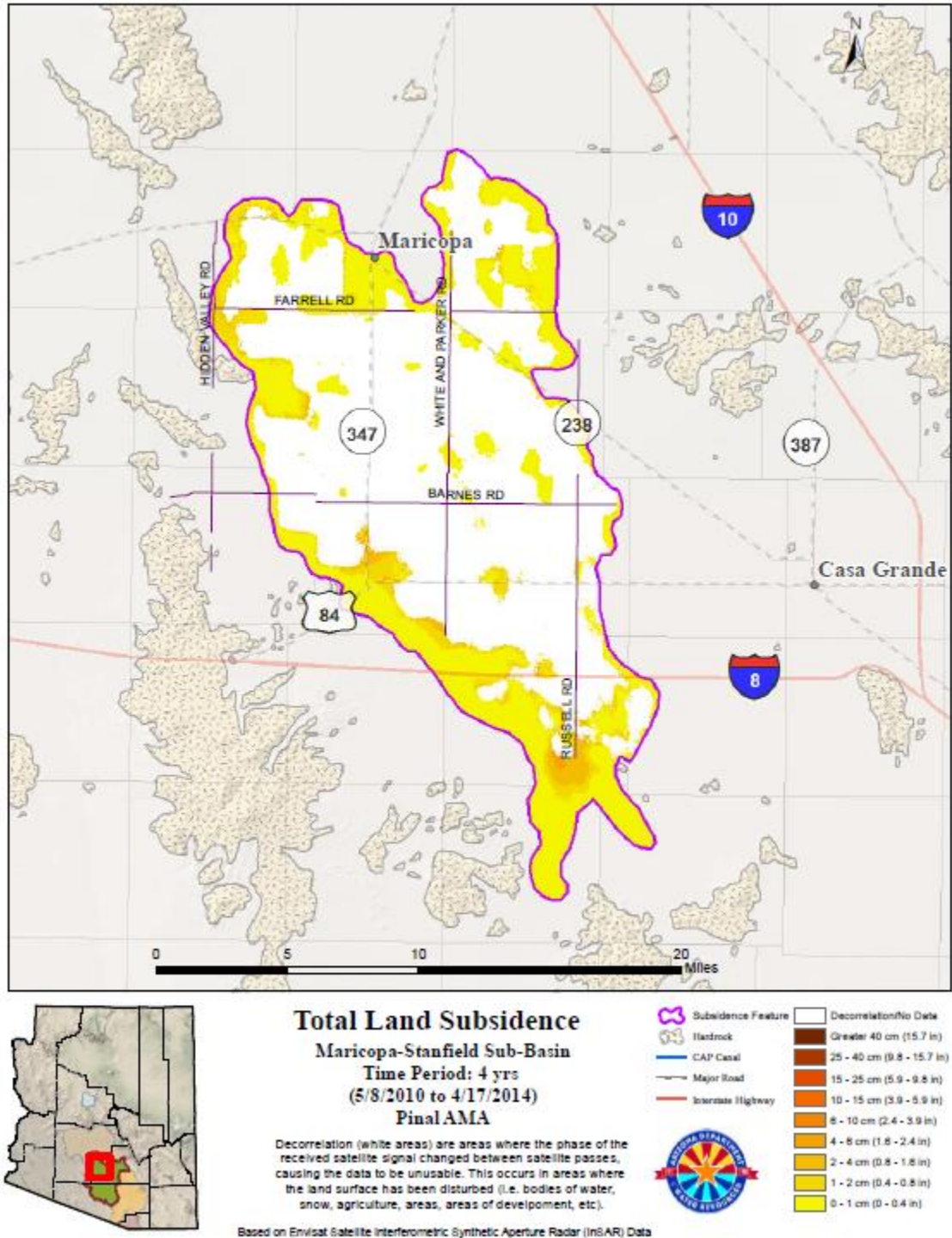
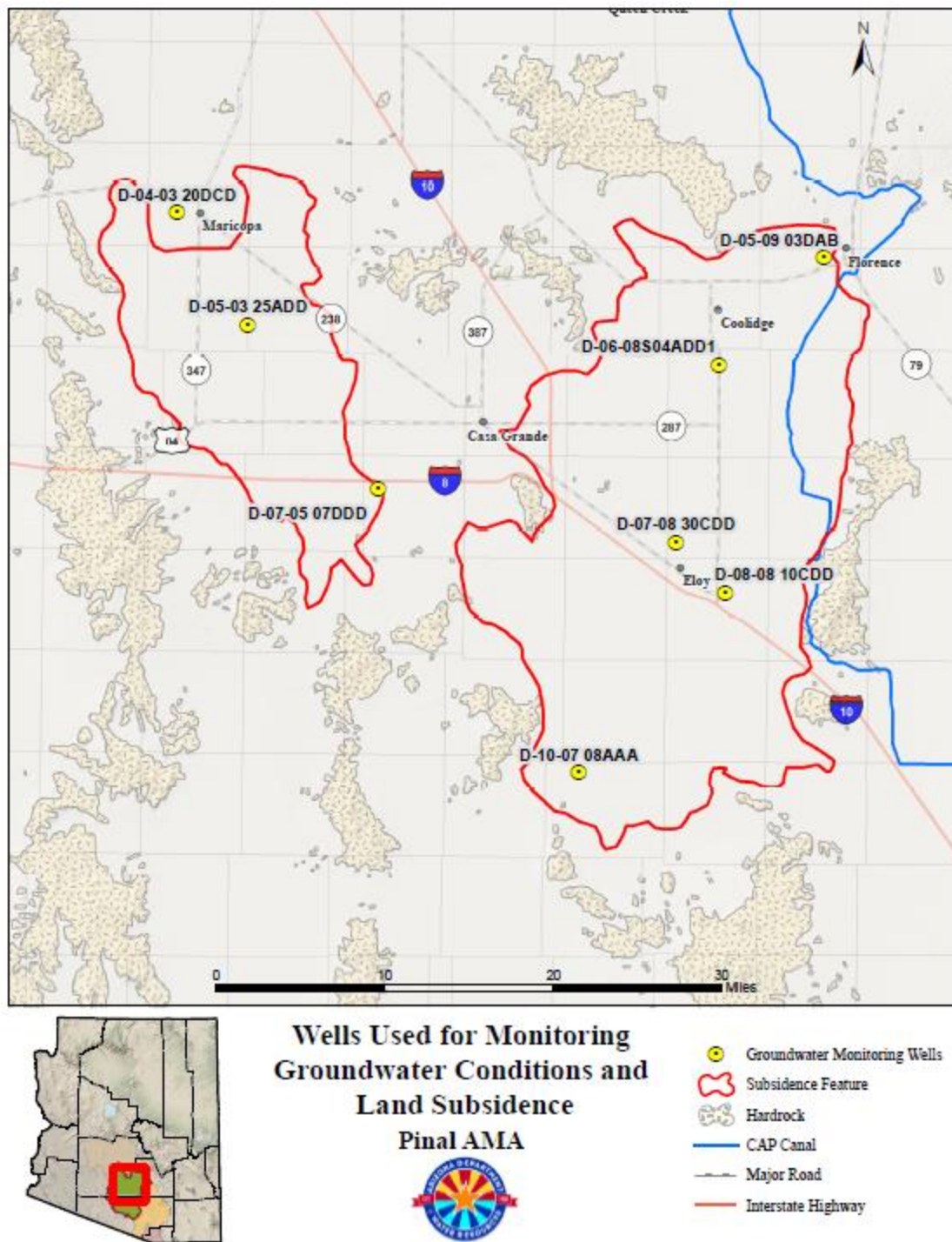


FIGURE 2-24
GROUNDWATER MONITORING WELLS IN THE PINAL AMA



2.8 GROUNDWATER QUALITY LIMITATIONS ON SUPPLY

With respect to patterns of water use as they currently exist, the quality of most PAMA groundwater and surface water supplies tends to be within the acceptable range of both state and federal standards. While water quality in the PAMA is more fully described in Chapter 7, this section summarizes water quality effects on supply where the use of certain water supplies is restricted by chemistry or contamination.

A 2005-06 Arizona Department of Environmental Quality (ADEQ) baseline groundwater quality study (Towne, 2008) found the groundwater in the PAMA to be generally slightly alkaline, fresh and hard-to-very hard and indicated that the greatest impact to groundwater quality in the PAMA is from the effects of salts and calcite concentrated by evaporation during irrigation.

The study included 86 sites with 70 percent (60 sites) exceeding at least one health-based, federal or state water quality standard and included arsenic, fluoride, gross alpha, nitrate and uranium. The standards used to evaluate water quality included the Federal Safe Drinking Water (SDW) Primary Maximum Contaminant Levels (MCLs), the State of Arizona Aquifer Water Quality Standards and the Federal SDW Secondary MCLs. These standards are based on the water's suitability for human consumption, not necessarily the quality required of irrigation water used to grow crops. With the exception of nitrate exceedances resulting from the use of fertilizer and human and animal wastewater, the constituents detected were naturally occurring. Other exceedances included arsenic, fluoride, gross alpha and uranium. The lowering of the arsenic standard from 0.05 mg/l to 0.01 mg/l in 2006 resulted in more exceedances (33) than would have prior to the change (just one).

Each sample was also assessed as to its suitability for irrigation based on salinity and sodium hazards. The results indicated that the majority of the samples had a medium or high salinity hazard and low to medium sodium or alkali hazard (Towne, 2008). In those locations where the salinity of groundwater exceeds 1,000 parts per million (ppm) of total dissolved solids (TDS), the effects of these levels on soils and crop production can be mitigated by leaching and crop rotation.

Public water systems are subject to SDW regulations and require treatment to remove contaminants before the water supply can be provided to a municipality, but domestic wells are not (Towne & Jones, 2011). Individual domestic well owners are advised to have their well water tested and treated if necessary. Treatment may include diluting the groundwater with non-contaminated water supplies or by well abandonment and replacement.

Agricultural activities are considered to be nonpoint sources of groundwater contamination and are not comprehensively addressed by ADEQ regulatory programs (Towne & Jones, 2011). The EPA's Clean Water Act exempts water used for agriculture and runoff from agricultural activities (EPA, 2015). There are some guidelines for the evaluation of water quality for irrigation provided in a 1976 publication, updated in 1985 from United Nations Food and Agriculture Organization (Ayers & Westcot, 1985). Additionally, the National Sustainable Agricultural Coalition has proposed agricultural water standards for the growing, harvesting, packing and holding of produce for human consumption (fruits and vegetables) but does not address other types of crops (NSAC, 2015). The majority of the crops grown in PAMA are cotton and animal feed crops.

For more information on water quality in the PAMA, see Chapter 7 of this plan.

2.9 AVAILABILITY AND UTILIZATION OF RENEWABLE SUPPLIES

To preserve the agricultural economy for as long as feasible and preserve water supplies for future uses the PAMA groundwater reliance must be reduced and renewable water supply use increased. Gila River surface water, treated reclaimed water, and CAP surface water are currently available renewable supplies in the PAMA. The continued ability to effectively utilize CAP surface water and reclaimed water throughout the PAMA will significantly affect the PAMA's ability to reach and maintain its water management goal. The historical direct use of renewable supplies is described in detail in Chapter 3.

2.9.1 Reclaimed Water

In 2015 the total reclaimed water production reported to ADWR on Annual Water Withdrawal and Use Reports in the PAMA was 6,524 ac-ft. However, ADWR has estimated that the actual total production in the PAMA in 2015 was closer to 21,000 ac-ft. Not all wastewater production is reported to ADWR. This is because many wastewater treatment facilities are not owned and operated by municipal providers, and therefore, the information is not required to be reported to ADWR by those facilities that ADWR does not regulate. The majority of this reclaimed water was treated by the City of Casa Grande. Smaller amounts of reclaimed water were treated at a number of smaller capacity sub-regional plants. The majority of the reclaimed water is discharged into the Santa Cruz River where it infiltrates into the regional aquifer. Some of the reclaimed water generated at the regional plants is delivered to agricultural users or turf facilities within the PAMA. Deliveries of reclaimed water for direct use from 2005 to 2015 averaged 3,900 ac-ft per year. A small portion of the reclaimed water is recharged at constructed underground storage facility sites or at on-site seepage basins at the sub-regional treatment facilities. Increased reuse and recharge of reclaimed water would reduce the need to pump groundwater and help minimize water level declines.

2.9.2 CAP Surface Water

CAP surface water is the most abundant renewable water supply in the PAMA. CAP allocations available to the PAMA total more than 15,000 ac-ft of water. In addition, the Ak-Chin Indian Community holds 75,000 ac-ft and the GRIC holds 311,800 ac-ft of subcontract water. See Chapter 8 of this plan for a listing of CAP allocations in the PAMA and a map of the locations of the recharge facilities. Table 2-7 lists the Underground Storage Facilities (USFs) and Groundwater Savings Facilities (GSFs) in the PAMA. Between 2000 and 2014, approximately 2.0 million ac-ft of CAP water was recharged at permitted USFs or GSFs in the PAMA.

The majority of water storage in the PAMA occurs at GSFs, where CAP water is used directly by the agricultural sector. GSF CAP is provided to farms participating in ADWR's GSF program. At GSFs, CAP water is used in lieu of groundwater and the water storer receives credit for the groundwater "saved," which can then be used by the water storer in the future. From 2000 to 2014, CAP water use at GSFs has averaged approximately 133,900 ac-ft per year. CAP surface water is also supplied to the Ak-Chin and GRIC for agricultural purposes. The total CAP water supplied to tribal lands for agricultural purposes from 2000 to 2015 was approximately 1.3 million ac-ft.

2.9.3 Non-CAP Surface Water

In addition to CAP surface water, the SCIP delivers surface water for tribal agricultural irrigation and the San Carlos Irrigation and Drainage District delivers surface water for non-tribal agricultural irrigation and a small amount of urban irrigation. The volume of surface water delivered varies from year to year. In 2015, about 98,000 ac-ft of surface water was used in the PAMA.

TABLE 2-7
PINAL AMA UNDERGROUND STORAGE & GROUNDWATER SAVINGS FACILITIES

Right Number	Permittee	Facility Name	Facility Type	Type of Water Recharged
71-209000	Arizona City Sanitary District	Arizona City Sanitary District	Constructed	Reclaimed
72-531382	Central Arizona Irr. & Drainage District	Central Arizona Irrigation & Drainage District	GSF	CAP
71-221491	City of Casa Grande	Casa Grande Constructed Recharge Facility	Constructed	Reclaimed
71-221492	City of Casa Grande	Casa Grande Managed Recharge Facility	Managed	Reclaimed
71-591932	City of Eloy	Eloy Reclaimed Recharge Project	Constructed	Reclaimed
71-220045	Corrections Corp. of America	Eloy Detention Center USF	Constructed	Reclaimed
71-211279	Global Water – Palo Verde Utilities Co.	Global Water – Palo Verde Utilities Company	Constructed	Reclaimed
71-216374	Global Water – Palo Verde Utilities Co.	Southwest Water Reclamation Facility (Campus 2)	Constructed	Reclaimed
72-534489	Hohokam Irrigation & Drainage District	Hohokam Irrigation and Drainage District GSF	GSF	CAP
71-211290	Johnson Utilities	Anthem at Merrill Ranch Recharge Facility	Constructed	Reclaimed
72-531381	Maricopa-Stanfield Irr. & Drainage District	Maricopa-Stanfield Irrigation and Drainage District GSF	GSF	CAP
71-211286	Picacho Sewer Company	EJR Ranch USF	Constructed	Reclaimed
71-591938	Picacho Sewer Company	Sun Lakes at Casa Grande Reclaimed Recharge Facility	Constructed	Reclaimed
71-211285	Santa Rosa Utility Co.	Santa Rosa Utility Company USF	Constructed	Reclaimed

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